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ABSTRACT

Contained in this monograph is a review and synthesis of developmental psychology and learning theory, with major emphasis upon applications of the developmental perspective to environmental education curriculum and instruction. Based upon a summary of the work of Piaget and his followers, a learning readiness axis is proposed. Also examined are how selected instructional implications of learning theory, such as Gagne's learning hierarchies, can relate to cognitive development. Modules developed by the Far West Laboratory for Educational Research and Development are drawn upon to illustrate the application of the psychological constructs discussed to the learning of environmental concepts. Both subject matter and process skills are viewed as subordinate learning hierarchies that lead to an understanding of the environmental system being studied. To be consistent with the developmental readiness of most learners, it is recommended that educators prepare learning activities appropriate for students in the transition between the representational (concrete) and formal operations periods. Provided in the appendix is a review of current developmental research. (WB)

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AN EXPLORATORY ANALYSIS OF READINESS FOR ENVIRONMENTAL EDUCATION

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AN EXPLORATORY ANALYSIS OF READINESS FOR ENVIRONMENTAL EDUCATION

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EXECUTIVE SUMMARY

This monograph reviews the developmental and cognitive literature in a broad, general way and suggests possible applications of the developmental perspective to the practical problems of environmental education. It is not a comprehensive review of the developmental, cognitive, or environmental education literature. It is an attempt to synthesize a practical developmental perspective and to encourage environmental educators to consider this perspective in curriculum design and planning.

The monograph begins with a review of the developmental psychology of Jean Piaget. Piaget has argued that children pass through four stages on their way to adult reasoning: (1) the Sensorimotor Period, (2) the Preoperational Period, (3) the Representational Period, (4) the Formal Operations Period. Developmentalists have always considered chronological age as a poor predictor of a child's abilities. Piaget's claim is that children must pass through each successive period in order to get to the next higher period. He also believes that in each successive period children conceptualize their world in a more effective way.

The recent work of neo-Piagetians approaching development from an information-processing and problem-solving perspective is also examined in some detail.

Our review of the rapidly growing developmental literature can be summarized by the following generalizations:

- Piaget's data base is very strong and any developmental theory must begin by explaining Piaget's findings.
- Piaget's theoretical constructs are vague or contradictory and are increasingly disputed.
- There are a number of neo-Piagetians, the most notable coming from the perspective of information processing, who have developed interesting, specific theories. At the moment, however, these theories do not support broad generalizations.
- The research in the area of developmental psychology is vigorous and applications should improve rapidly in the next few years.

As a practical matter, we believe environmental educators and curriculum designers should:

- Retain Piaget's overall classification, while
- Using the theoretical insights of the neo-Piagetian to clarify the meaning of Piaget's data. No neo-Piagetian theory, however, should be condidered as more than a tentative and temporary construct.

Curriculum designers concerned with elementary, high school, college, and adult education should be concerned with two developmental periods--the Representational Period and the Formal Operations Period--and the transition between them. By keeping in mind the characteristics typical of each of these periods, designers can predict which instructional sequences are most likely to be effective at what time.

To aid in conceptualizing the impact of development on learning, this monograph presents a Learning Readiness Axis that can be placed on the vertical side of an instructional sequence to indicate the approximate sequence of development. This axis is introduced in Figure 1.

DEVELOPMENTAL PERIOD	IMPORTANT CHARACTERISTICS
FORMAL OPERATIONS PERIOD	Abstract concepts of functions and the ability to hypothesize possible variables or outcomes.
TRANSITION	
REPRESENTATIONAL PERIOD	Elaborate Representational Models and Hierarchies Reversibility [A]⟷[B]
TRANSITION	
PREOPERATIONAL PERIOD	Mapping [A]→[B]

Figure 1. A LEARNING READINESS AXIS

The extensive appendix at the end of this monograph reviews the current research in development for readers who wish to extend or refresh their understanding of the Piagetian stages of development.

We conclude our discussion of development by urging that environmental educators assume that some--if not most--of their potential audience is likely to approach the subject from a Representational rather than a Formal perspective.

Following the discussion of development, the monograph reviews current formulations of learning theory, including objectives and hierarchies. This, in turn, leads to a discussion of the environmental learning knowledge base. The potential hierarchies of environmental learning concepts and skills are found to be very large. The modular approach of the Far West Laboratory for Educational Research and Develpment (FWL)* is examined, however, and found manageable. FWL constructs independent, small hierarchies of skills and subject matter concepts for each component and interaction to be considered in a particular instructional unit.

The apex of many subject matter and skill hierarchies is a single, holistic interacting system. This concept is illustrated in Figure 2. Our examination of the assumptions guiding the development of various instructional programs leads us to conclude that most programs attempt to teach a number of formal concepts. What we propose, as a result of our review of the developmental literature, is that the objectives of an instructional program, whenever possible, be designed to call for behavior that is typical of the transition between the Representational and Formal Periods, and that there be both Representational and Formal interpretations of these objectives. The instructional program itself should be conceptualized as lying in the transition period. This is meant to indicate that a student who is not capable of Formal Operations will nonetheless be able to comprehend instruction on a Representational level.

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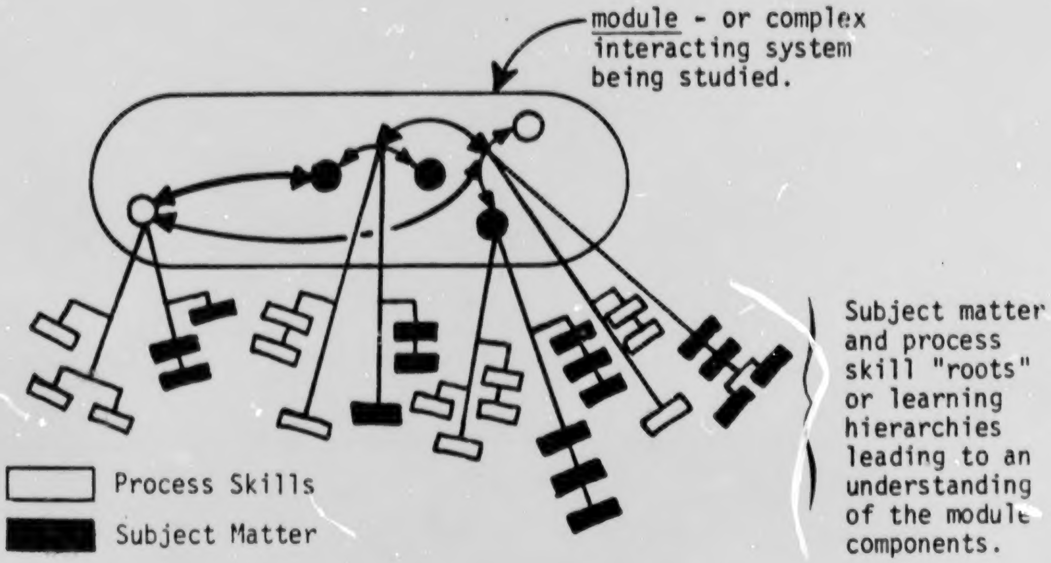
*The four teacher training modules produced by the FWL are: Optimal Use of Finite Land Resources, Energy Intensive Urban Growth and Quality of Life, Energy-Conserving Resource Utilization, and Energy Resource Delivery Use.


module - or complex interacting system being studied.

Subject matter and process skill "roots" or learning hierarchies leading to an understanding of the module components.

Figure 2. A SYSTEMIC PORTRAYAL OF ENVIRONMENTAL EDUCATION LEARNING HIERARCHIES

In the example that follows we picture the interaction arrow (1) in an instructional unit as the basis of at least two hierarchies: (a) a hierarchy of process skills and (b) a hierarchy of subject matter concepts. Both of these hierarchies would be constructed entirely in terms of abilities and concepts that a Representational student is capable of mastering. Thus the instructional unit itself should be entirely comprehensible, at the Representational level, to a student who is not capable of Formal Operations.

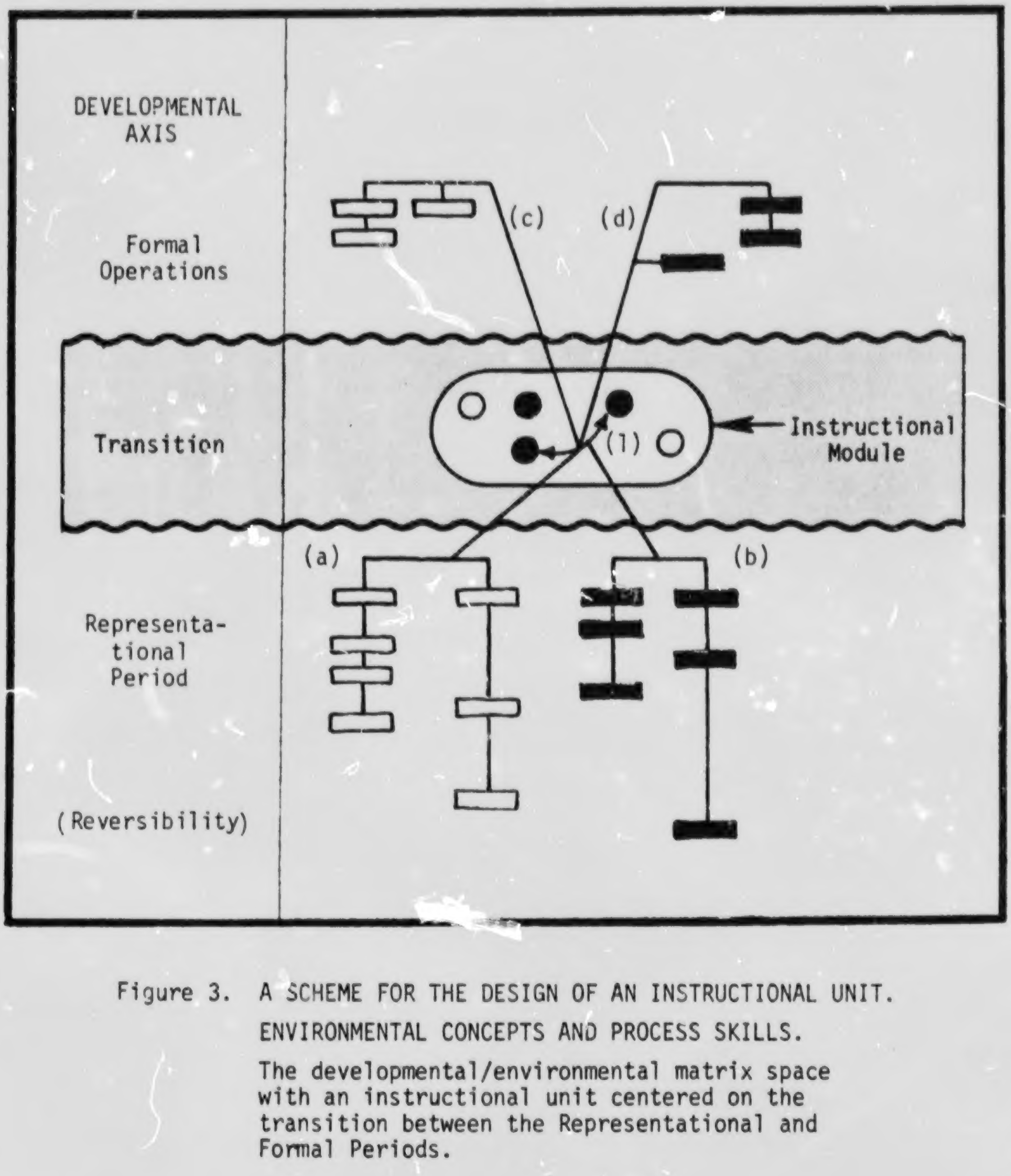

DEVELOPMENTAL AXIS
Formal Operations
(c)
(d)
Transition
(1)
Instructional Module
(a)
(b)
Representational Period
(Reversibility)

Figure 3. A SCHEME FOR THE DESIGN OF AN INSTRUCTIONAL UNIT. ENVIRONMENTAL CONCEPTS AND PROCESS SKILLS.

The developmental/environmental matrix space with an instructional unit centered on the transition between the Representational and Formal Periods.

We further propose that hierarchies of (c) Formal Operational processes and (d) subject matter be included in the instructional unit as enrichment. Thus, the model should be capable of being viewed entirely in Representational terms, in Formal terms, or as a mixture of the two modes.

We do not believe that such a design will be easy to arrange, but we believe the extra effort will offer significant advantages, namely:

- It will assure that those who are not yet capable of Formal Operational thought will nonetheless be able to understand the essential instructional contents.
- Since it is open to two interpretations, the design will aid Representational students in the transition to Formal Operations.
- Since it is open to a Formal interpretation, the design will not limit students capable of Formal Operations.
- Since it includes both Representational and Formal interpretations, it will also provide a means for assessing the level at which participating students are operating.

We have already noted that any specific formal concepts or intellectual processes can probably be taught to students operating at the Representational level, but that this requires a considerable instructional effort and the resulting skills and knowledge are neither well retained nor easily generalized. We believe that any substantial curriculum design and instructional development effort would be better advised to concentrate on developing materials that can be comprehended at the Representational level, so that the emphasis is on the opportunity to exercise existing skills and, thus, to make the transition to Formal Operations in a natural manner.

In the Summary section we propose a number of projects that could increase the awareness of environmental educators to the developmental and conceptual readiness of their students.

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INTRODUCTION

> In the associationist tradition that, under the guise of learning theory, dominated American psychology for so many years, it was assumed that children acquire knowledge bit by bit, storehousing discrete pieces of information....
>
> The structuralist tradition, in opposition to the associationist, maintains that concepts are by no means independent or unrelated, but, instead, are bound to one another by common structural features.... The implication of the structuralist tradition is that there are predictable regularities in a child's development of knowledge, due primarily to a human tendency to construe the world according to universal structures or patterns. With development, these patterns become more complex, differentiated, and adaptive.
>
> William Damon (1977)

Many environmental educators have considered the systems approach as a particularly valid way of approaching the communication of environmentally pertinent information. Some have suggested that environmentalists necessarily think in terms of systems. Moreover, many of those who have come to this conclusion have also felt that environmental education problems must be approached by teaching students about successively more complex systems. One sequence might be: (1) the individual as a system, (2) the household as a system, and (3) the neighborhood as a system. Another might be: (1) static systems, (2) open systems, (3) cybernetic systems, and (4) evolving systems. Still another sequence might be: (1) physical systems, (2) biological systems, (3) social systems, (4) cognitive systems. Indeed, many who have explored history come to the conclusion that the evolution of human thought represents successively more complex ways of modelling the world and the data we derive from it (Jantsch and Waddington, 1976; Warfield, 1976; Banathy, 1973; and Bertalanffy, 1968).

Systems theorists are naturally sympathetic to the work of Jean Piaget and other developmentalists who maintain, though by means of a slightly different technical language, that children's ability to understand the world grows through successive periods. As children move from one period to the next, their ability to conceptualize the world and to develop a cognitive model of reality becomes more complex, differentiated, and adaptive. Each of these successive periods can be thought of as a more or less complete systems model of the events and structures with which the child must interact. The result of this evolution is an adult capable of understanding the models that other adults use to conceptualize the world.

THE ORGANIZATION OF THIS MONOGRAPH

The argument of this monograph is presented in five successive chapters:

Chapter I begins by reviewing the main features of the developmental and cognitive literature. It concludes by proposing a learning readiness axis that describes the major features of the developmental sequence.

Chapter II briefly reviews the most important insights of learning theorists and considers how these can be synthesized with the findings of developmental psychology.

Chapters III and IV apply the preceding to the specific problems faced by environmental educators. These chapters draw heavily on the environmental curriculum currently being designed by the Far West Laboratory for Educational Research and Development.

Finally, Chapter V summarizes our thinking and recommends ways in which the developmental perspective can be applied to specific areas of concern to environmental educators. Based on the ideas developed here, recommendations for future research and development are proposed.

Rather than introduce many technical details regarding the methodology and the specific findings of developmental researchers into the body of the paper, an extensive appendix is included for those who would like to consider these matters in greater detail.

SOME BASIC DEFINITIONS

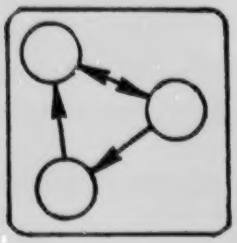
For the purposes of this monograph, we will define a few commonly used terms in the context of the subject matter we wish to discuss. The important point we will make is that thinking and problem solving may be viewed as model building. Learning, in turn, is described as the evolution of models from more primitive to more sophisticated forms. Finally, a common language with which to describe differing theories of cognitive development must allow us to describe the models by means of which it is postulated that children think. In this monograph we will employ the "language" of general systems theory.

A simple rule. A simple rule is a conditional statement. For example, "If the sun is out then it will be warm." We could write this generally as: "If p then q." We use such simple rules to connect concepts; in this case, the concept of the sun being out and the concept of warmth. Both are concepts about things. There is also a relation or transformation represented by the words, "If...then...," which simply means q "becomes" or "co-occurs with" p. We could substitute systems theory terminology and refer to concept p as "system state p," and say that state p will be followed by state q.

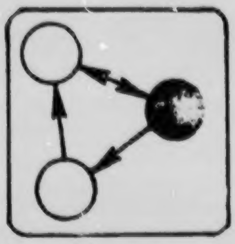
Complex rules or models. Complex rules involve more than two concepts and/or transformations. In systems theory such complex rules are generally referred to as models. Models suggest more complex predictions.

For example, if we had a three-state model,

thus:

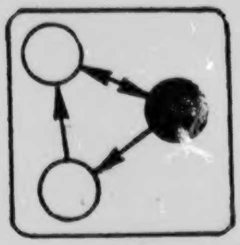


and the initial state was, thus:

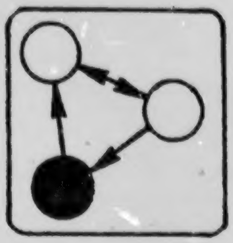


There are many possible subsequent states. For example:

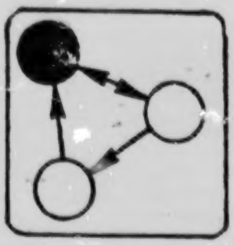
If



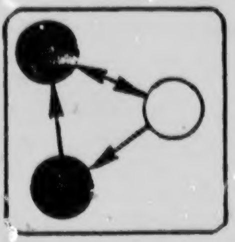
then (1)



or (2)



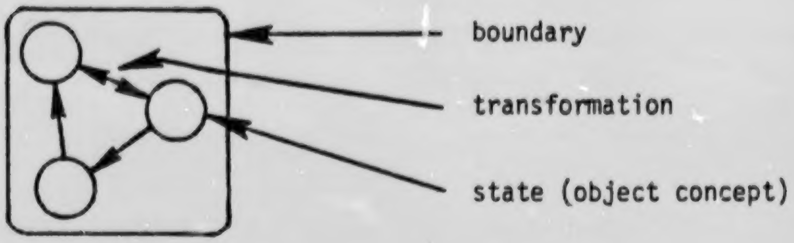
or (3)



In this example, we have not described the transformational rules. In a more complex example there could be qualifications, like "only one arrow (path) can be utilized at a time" or "both paths must be used simultaneously to have an effect," and so forth.

The basic components of models. For our purposes, we can think of models as having three basic components: (1) states or objects, (2) transformations or processes, and (3) a boundary.

Model



The boundary is simply the hierarchically higher concept that contains or subsumes all of the objects and relations that make up a particular model. In more practical terms, the boundary is the problem situation (e.g., an instuctional task). The states are all of the objects or variables involved in the problem, and the transformations refer to all of the manipulations or changes that can occur. The solution to a particular problem comes only after (1) the states are fully specified and (2) the possible transformations of states are understood.

Comparing models. Students can understand and use models to make predictions; however, their predictions are always limited by the power of the model they employ. The power of predictions increases with the number of states included in the model and the number and type of transformations allowed. A precondition to the use of any model, however, is that the student be able to recognize that a particular model applies to the specific problem the student is trying to solve.

Higher order problem solving requires that students first build a model for the problem situation and then draw predictions from it. We suggest that students do this by means of analogies or metaphors. The student begins by conceptualizing the problem in terms of a model with which he or she is already familiar. Then the student seeks to develop a new model that more adequately represents the situation. Problem solving proceeds as the new model is successively refined.

Students (or for that matter, scientists, artists and other creative problem solvers) begin with some real situation (A) and select a model that is in some way similar (B). As shown in Figure 4, a new model (C) is synthesized. The new model uses the general form of the initial model (B) while simultaneously accommodating the unique features of the actual situation (A). Implications or predictions are drawn from C and tested. Experience may indicate that adaptations are needed. Or it may indicate that a different initial model (B) would be more appropriate. Eventually, students decide that C is an appropriate fit and use that model to solve the problem. If students are asked to explain their solution, they will often describe the original analog model. That is, we may see problem solving behavior that cannot be fully accounted for by students' explanations. The metaphoric process lies at the heart of both generalization and communication. It is only relatively late in development, however, that one learns to reflect on the thought process itself.

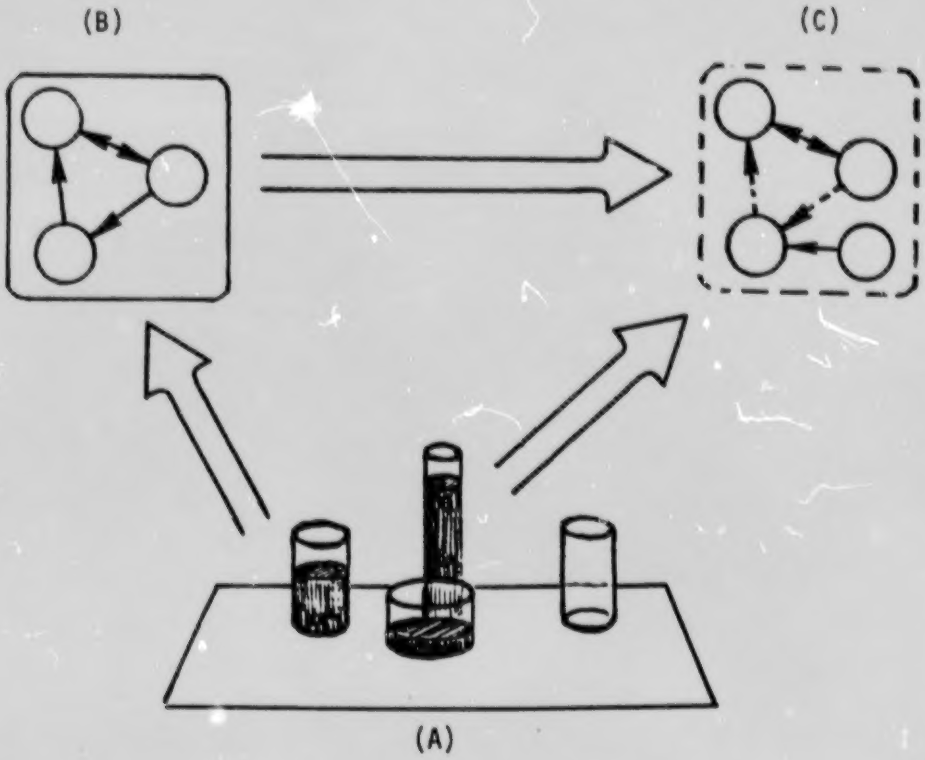


Figure 4. A PARADIGM FOR THE DEVELOPMENT OF MODELS

Our aim here has been to provide a language to which we can map developmental theory and environmental education. In the discussions that follow, we will identify the kinds of models that developmental theories suggest students typically use. We will also discuss models latent in the curricula of environmental education. Readiness will become the comparison of the student's ability to conceptualize with the information to be understood, each represented by models. Our final goal will be a sequential, periodic alignment of environmental models with student models to form a developmental curriculum.

I. READINESS FOR LEARNING

In the second edition of The Conditions of Learning, Gagné (1970) summarizes the question of the developmental readiness for learning as follows:

> Readiness for learning...implies (that) there are certain conditions that precede the learning even itself and that operate to determine the probability of its occurrence....
>
> How such internal conditions can best be described is not a matter that can be confidently stated at the present time. It may be that the answer may best be sought in stages of maturation, innately determined by patterns of neural growth (see Gesell, 1928). A child of seven, for example, may be able to undertake learning tasks impossible to a four-year-old because of differences between them in their stage of nervous system maturation, analogous to the obvious differences in their other bodily structures. Alternatively, the kinds of learning that can be accomplished may be limited by the existence of certain cognitive schemata, developed by a process of adaptation, which is the essence of the ideas put forward by Piaget (see Flavell, 1963; Phillips, 1969). Contrasting with these views is the notion that, beyond a certain early age (perhaps three), developmental readiness for learning is primarily determined by previously acquired intellectual skills, and therefore by the cumulative effects of learning and learning transfer (Gagné, 1970).

Since Gagné's summary, considerable research has examined the problem, but a solution can still not be confidently stated at the present time. We can, however, present a clearer picture than Gagné was able to present in 1970.

To consider each of Gagné's three options:

- *Stages of maturation innately determined by patterns of neural growth.* This area is being vigorously studied but has not, as yet, produced any results that are not easily explained by simpler theories. For the moment, the neural bases of development remain largely irrelevant.

- *Cognitive schemata developed by a process of adaptation.* This area is dominated by the Piagetian model, and it has proved fruitful. The recent work of cognitive developmental psychologists has produced a number of useful guidelines for instruction and curriculum design. It is in this area that we will concentrate throughout the remainder of this section.

- *The cumulative effects of learning and learning transfer.* This area, the one that Gagné favored, has not proved as fruitful as it seemed likely that it might in 1970. Additional research in the bahavioral learning tradition has clarified several developmental issues, but has proved incapable, by itself, of explaining the marked periodicity in learning demonstrated by Piaget and others working in the cognitive/developmental tradition. Alternately, it is clear that the traditional learning theory approach has proved much more powerful than Piaget has ever admitted. Indeed, we expect to see the rapid emergence of more powerful, integrated developmental/learning models. We will consider the interaction between learning and development in Chapter II.

PIAGETIAN DEVELOPMENTAL PSYCHOLOGY

The field of developmental psychology is currently dynamic. The major paradigm of the field is the model of development proposed by Jean Piaget. Our review of the rapidly growing literature can be summarized by the following generalizations:

- Piaget's data base is very strong and any developmental theory must begin by explaining Piaget's findings.

- Piaget's theoretical constructs are vague or contradictory and are coming under increasing attack.

- There are a number of neo-Piagetians, the most notable coming from the perspective of information processing, who have established interesting but specific findings. At the moment, however, these findings do not support broad generalizations.

- The research in the area of developmental psychology is vigorous and educational applications should become clearer in the next few years.

Thus, as a practical matter, we suggest educators and curriculum designers should:

- retain Piaget's basic classification, and
- use the theoretical insights of the neo-Piagetian to clarify the meaning of Piaget's data. Neo-Piagetian theories, however, should be considered as tentative and temporary.

In keeping with these suggestions, this chapter will begin by reviewing Piaget's basic theory of the developmental periods. Then we will consider two of Piaget's developmental periods in more detail.

Piaget and His Theory

Jean Piaget was born in 1896 at Neu Châtel, Switzerland. He took his doctorate in zoology in 1918 but has spent the years since then in the study of the psychology of children. Piaget's first research was concerned with testing intelligence. Instead of focusing on the right answers, however, he became interested in determining why children got the wrong answers. From his earliest years Piaget was concerned with the biological and environmental bases of intellectual thought. He was especially concerned with how a human being can unite discrete experiences into a general or holistic conception of the world. Piaget describes the concerns that have guided his research effort over the past sixty years as follows:

> I felt...that, in utilizing for psychological experimentation the mental habits I had acquired in zoology, I would perhaps succeed in solving problems of sturctures-of-the-whole....It became clear to me that the theory of the relations between the whole and part can be studied experimentally through analysis of the psychological processes underlying logical operations (Evans, 1973).

Piaget calls his approach "genetic epistemology" to stress that he is concerned with the relationship between biological development on the one hand and logical or philosophical development on the other. Piaget's first books, including The Language and Thought of the Child (1924), The Child's Conception of the World (1929), The Child's Conception of Causality (1927), Judgment and Reasoning in the Child (1928), and The Moral Judgment of the Child (1932), established his reputation and initiated a revolution in the way psychologists think about children.

Piaget reported a number of simple, clever experiments designed to demonstrate the way children conceptualize the world.* The experiments always employ what Piaget calls a "clinical method." A task is set before a child and after an initial response, the experimenter continues to probe until satisfied that the child's explanation and assumptions are clear. The protocols of conversations between the experimenter and child constitute the raw data of Piaget's studies. This non-statistical and non-standardized approach has created some difficulties for experimental psychologists, but it has led to a number of striking insights into the way children think. Indeed, Piaget's major acheivement has been to demonstrate how young children conceptualize the world and how their thinking differs from that of adults.

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*We have summarized some of the most important Piagetian and neo-Piagetian tasks in Appendix A for readers who are not familiar with them.

Piaget concluded that children pass through four periods on their way to adult reasoning:

The Sensorimotor Period -- Birth to 18 months
The Preoperational Period -- 18 months to 7 years
The Representational Period * -- 7 years to 12 years
The Formal Operations Period -- 12 years and above

The ages given are only approximate. Indeed, developmentalists have always regarded chronological age as a poor predictor of a child's abilities. Piaget's major claim is that the periods are ordinal; that is, children must pass through each in succession. He also believes that in each successive period children conceptualize their world in more complex and more effective ways.

Along with his description of the successive periods, Piaget offered a theory to explain the periods. In essence, Piaget's theory holds that children understand the world by means of a general model, gestalt, or worldview. The child's model has a biological or neurological base which is subsequently modified as the child interacts with the environment. Recent theorists have emphasized that the model can be reformulated in terms of memory storage or a retrieval strategy (Pascual-Leone, in Case, 1978a).

---

*Piaget called this period the "Concrete Operations Period." Throughout this paper, however, we will use Bruner's term, the "Representational Period," since we feel it is a more adequate description.

Piaget proposes that, during each period, the child interacts with the environment until he or she develops the generalized model appropriate to that period into its most effective and flexible form. Piaget terms this "equilibration." Once equilibrium is reached in any given period the child uses the model as a basis of understanding the world. As time passes, however, the child encounters contradictions that cannot be conceptualized by means of the model typical of that period. Finally, the model breaks down. After a transition period during which the child struggles to adapt the model, the child enters a new period and begins the process of consolidating a new and more sophisticated model.

If this explanation sounds rather like Kuhn's description of the development of a scientific paradigm, its subsequent breakdown, and the paradigm shift that follows, that would certainly be a good analogy (Kuhn, 1969; also Phillips, 1978). Indeed, Piaget draws heavily on the history of science to illustrate the historical development of conceptual thought. By analogy, during a particular period a child is engaged in what Kuhn calls "normal science." The child uses an equilibrated model to explore the world. When the child first begins to encounter difficulties, they are ignored. When the contradictions can no longer be ignored, a new paradigm emerges. This new paradigm is then refined during the subsequent period. Indeed, we could regard the child as progressing systematically from one model to the next, more adequate model, just as Kuhn suggests scientists proceed. However, all children seem to progress through similar models in a predictable sequence. This suggests common experiences. But since children raised in different environments and subject to very different experiences all seem to develop the same models in the same sequence, Piaget and other developmentalists have rejected this notion in favor of a more complex genetic interaction theory.

The models typical of the four periods can be described in a general way. During the Sensorimotor Period, before language develops, the child remembers specific visual stimuli and physical actions or manipulations. In essence, the child's model is comprised of a loose collection of action sequences that are recalled in the presence of specific stimuli. It is, very figuratively, as if the memories were stored in the senses and the muscles themselves.

During the Preoperational Period (18 months to 7 years) the child solves problems primarily by recalling visual images of similar situations. The child has language, but words are used primarily as signs rather than symbols. Thus, each noun phrase has a specific referent in the environment and words are used only when something in the environment stimulates their use. The child can represent objects or actions with imagery, but is limited to actual situations seen exclusively from the child's own perspective. During this period the child cannot effectively conceptualize the past or the future or imagine the viewpoint of another person.

The onset of Preoperational thought does not mean that the child no longer learns, conceptualizes, and remembers things by means of senses, physical actions, and manipulations. The Sensorimotor Period is contained within the Preoperational Period. In one sense Sensorimotor skills function as a separate independent mode of problem solving. In another sense Sensorimotor skills are combined with Preoperational skills. Words, for example, come to trigger complex sequences of Sensorimotor images and responses. Thus, each new period implies an ability to use new models while simultaneously continuing to include the ability to use older models in situations where they still seem appropriate. (This is illustrated in Figure 5.)

During the Representational Period (seven to twelve years) the child learns to use signs as symbols and is thus able to store memories in symbolic terms. The child is still constrained to the world of objects and can not yet conceptualize abstract or intangible concepts such as ratio and proportion, mathematical functions, and hypothetical possibilities. During the Representational Period, the child comes to conceptualize past and future time, to take another person's perspective, and to form elementary hierarchies of relationships between existing objects.

Finally, during the Formal Operations Period (12 years and above) the adolescent begins to approach problems with formal strategies. He or she can, for example, analyze situations by systematically controlling variables in complex problems, or by considering all of the hypothetical possibilities implicit in specific problems.

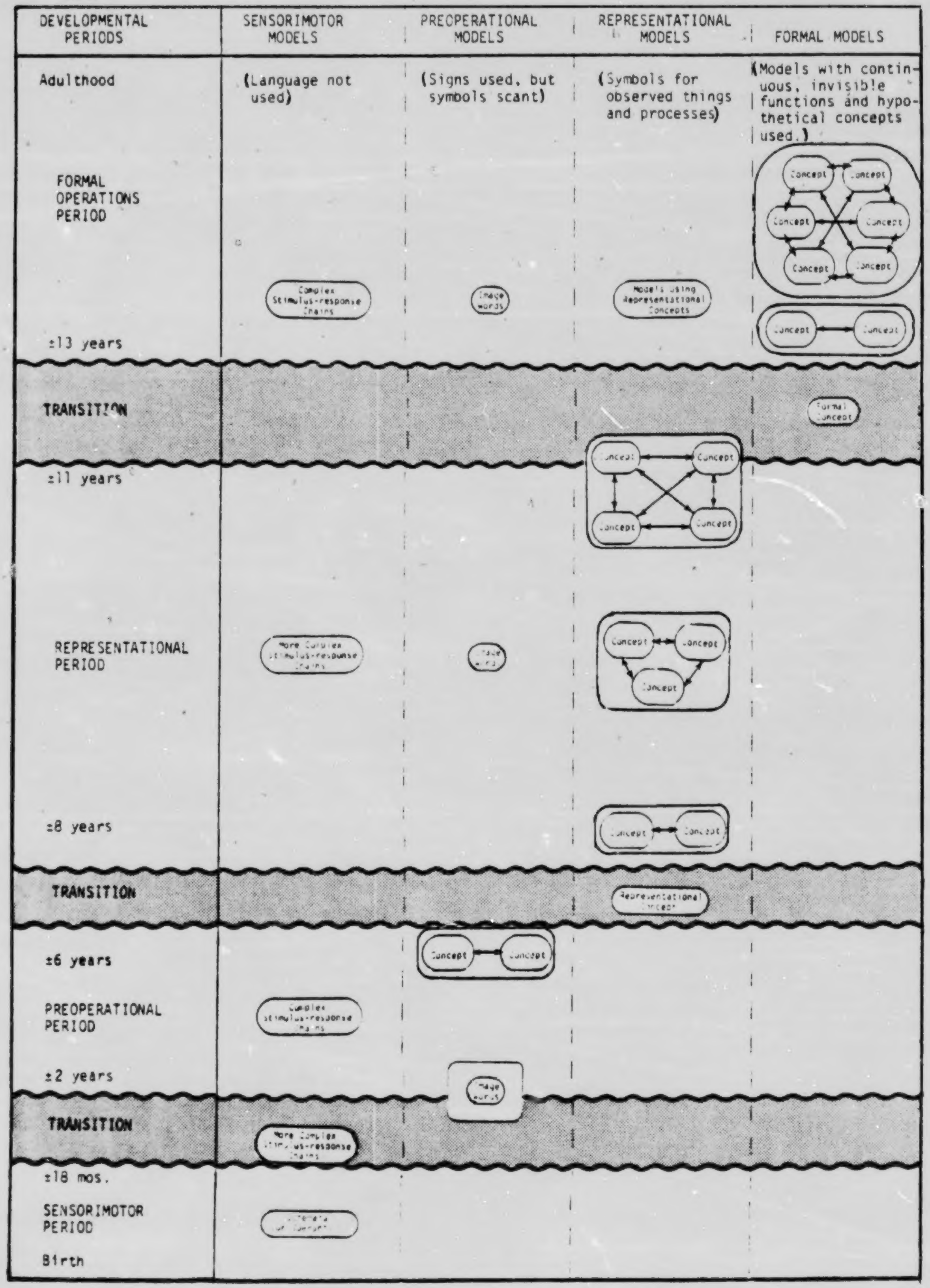

DEVELOPMENTAL PERIODS
SENSORIMOTOR MODELS
PREOPERATIONAL MODELS
REPRESENTATIONAL MODELS
FORMAL MODELS
Adulthood
(Language not used)
(Signs used, but symbols scant)
(Symbols for observed things and processes)
(Models with continuous, invisible functions and hypothetical concepts used.)
FORMAL OPERATIONS PERIOD
Concept
Complex Stimulus-response Chains
Image Words
Models using Representational Concepts
±13 years
TRANSITION
Formal Concept
±11 years
REPRESENTATIONAL PERIOD
More Complex Stimulus-response Chains
±8 years
TRANSITION
Representational Concept
±6 years
PREOPERATIONAL PERIOD
±2 years
TRANSITION
±18 mos.
SENSORIMOTOR PERIOD
Birth

Figure 5. BASIC MODELS AVAILABLE TO STUDENTS DURING DIFFERENT DEVELOPMENTAL PERIODS

What we are calling the Representational Period, Piaget terms the Concrete Operations Period.* Piaget defines an operation as "an internalized action which has become reversible and coordinated with other operations in a grouping, governed by the laws of the system as a whole" (Piaget, 1967). A child who is moving from the Sensorimotor Period to the Preoperational Period acquires the ability to store images and action schemata together as an image-word, but does not acquire reversibility. In Piagetian terms, reversibility comes with Representational thought and refers to the

---

*A field of study that sometimes seems to describe the Representational-Formal distinction in a different way is concerned with a student's perceptual style. A distinction is made between field dependency (Representational Operations?) and field independency (Formal Operations?). These perceptual differences have been found to correlate significantly with the Piagetian stages we have discussed in this article. The perceptual research, which is specifically focused on adults, has been investigated by Naval instructional technologists. For further information on this approach, see: Long, F.M., 1974; Pulos and Adi, 1977, and Linn and Pulos, 1978.

Another approach that also reminds one of the Representational-Formal distinction is the distinction that Jung made between extroverted psychological style (Representational?) and introverted style(Formal?). In describing the introverted style, Jung (1971) makes it sound very similar to a Piagetian description of a Formal Operator:

> [For the introverted style] facts are collected as evidence for a theory, never for their own sake. If ever this happens, it is merely a concession to the extraverted psychological style. Facts are of secondary importance for this kind of thinking; what seems to it of paramount importance is the development and presentation of the subjective idea, of the initial symbolic image hovering darkly before the mind's eye. Its aim is never an intellectual reconstruction of the concrete fact, but a shaping of that dark image into a luminous idea, and the creative power of this thinking shows itself when it actually creates an idea which, though not inherent in the concrete fact, is yet the most suitable abstract expression of it. Its task is completed when the idea it has fashioned seems to emerge so inevitably from the external facts that they actually prove its validity.

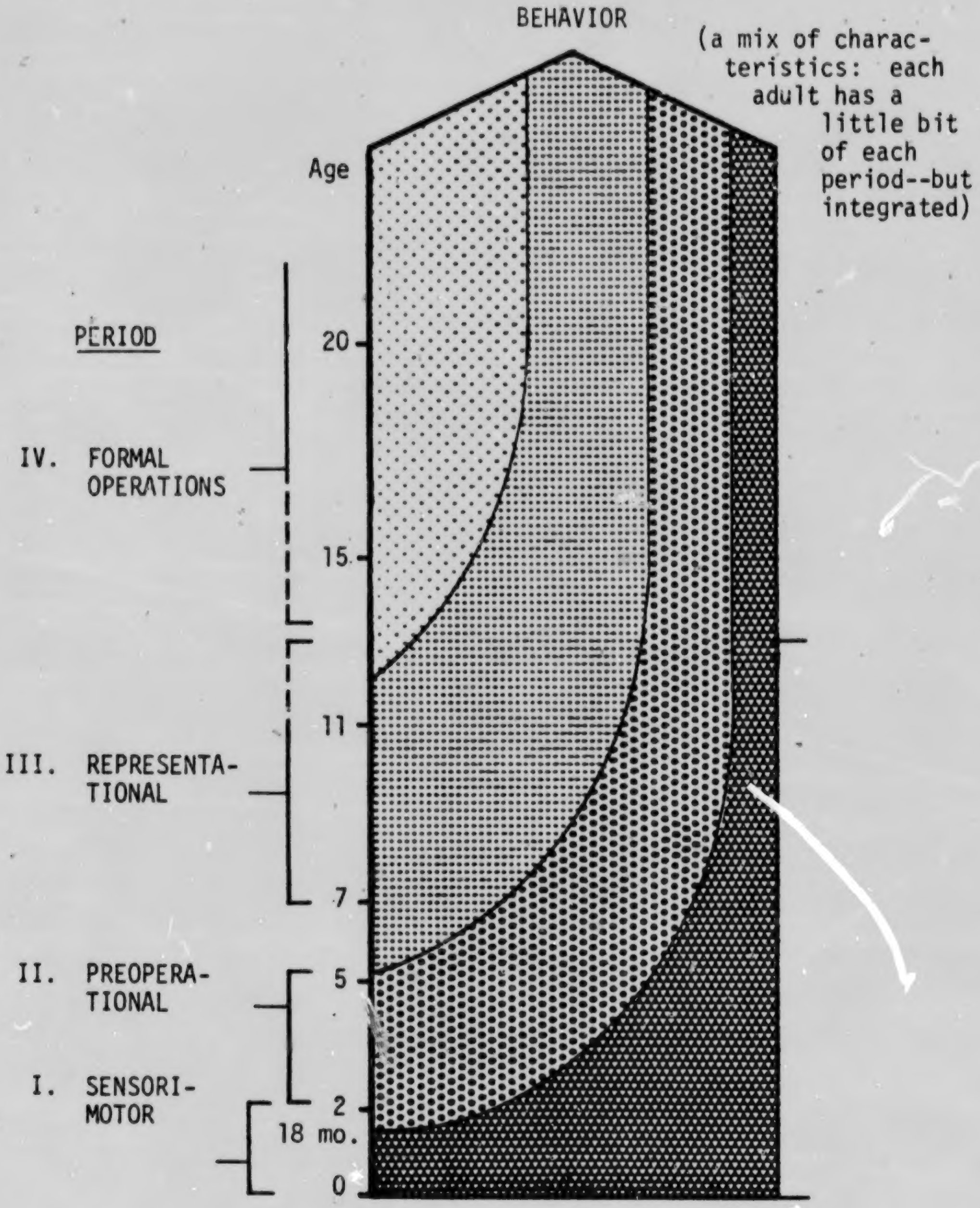

BEHAVIOR
(a mix of characteristics: each adult has a little bit of each period--but integrated)
Age
PERIOD
20
IV. FORMAL OPERATIONS
15
11
III. REPRESENTATIONAL
7
II. PREOPERATIONAL
5
I. SENSORI-MOTOR
2
18 mo.
0

Figure 6. PIAGET'S PERIODS OF INTELLECTUAL DEVELOPMENT (After Harmon, 1979)

ability to use two concepts simultaneously and, thus, to mentally examine their similarities. This idea of "simultaneous concepts," or reversability, is much akin to the notion that meaning involves two metaphors, each simultaneously being compared with the other. When the child becomes capable of using words or concepts in a reversible way, the child is said to be capable of operations. Implicit in this concept of reversibility and operations are the larger concepts of cause-and-effect and past, present and future since these complex concepts depend on the child's ability to alternate between successive images of reality.

During the Representational Period the child is capable of using words that refer to observable objects or processes. Later during the Formal Operations Period, the child is capable of using words that refer to abstract, invisible, hypothetical, or Formal concepts. Representational Operations are operations on operations (Figure 6).

Although Piaget has recently begun to equivocate, he has traditionally maintained that the periods are an invariable sequence that can not be altered by instruction. The child, for example, must live through and actively experience and conceptualize the world from a Preoperational perspective, before beginning to develop a Representational perspective.

Most current researchers have found Piaget's demonstration of the existence and the sequence of periods impressive. At the same time they have found less use for Piaget's theoretical explanation of how or why the child moves from one period to the next. We will learn now to a brief consideration of some of the current explanations of the dynamics behind a child's cognitive development.

NEO-PIAGETIAN MODELS AND RESEARCH

In recent years there has been a movement among cognitive psycologists to accept Piaget's descriptive conclusions while seeking a more adequate theory to explain the occurrence of the developmental periods. None of the neo-Piagetians has succeeded in proposing a completely satisfactory theory, but several have emphasized aspects of the developmental sequence that seem likely to lead to a more satisfactory neo-Piagetian theory.

We will briefly consider the models proposed by three neo-Piagetians: Case, Siegler, and Fischer. Each has some research to support his theory. In our opinion, however, no one of them has produced decisive evidence to establish his theory over the other contenders. Unfortunately, each has also considerably clouded issues by introducting new terminology and slightly different classification systems. In this review we will take the liberty of altering their verbal idiosyncracies and thus generalizing their results in order to compare their models more easily to Piaget's general classification.

Case's Working Memory Model

Case (1978a, 1978b) has proposed a parsimonious model of development which focuses on the working memory capacity required to solve a problem. This approach draws heavily on the information processing perspective that attempts to find analogies between thought processes and computer processes.

Working memory capacity refers to the number of items, units, or chunks of information that must be actively manipulated to solve a problem. The classic study of the human working memory capacity was done by Miller (1956). With data obtained from a number of arithmetic tests, Miller postulated that the average adult is capable of simultaneously keeping in mind five to nine independent pieces of information. Consider these examples: If we try to multiply two single digit numbers together, say 3 times 7, we can easily come up with the answer because it is already stored in our long-term memory. Hence, no more than three memory registers are needed: one for the 3, one for the 7, and one for the answer, 21. This task should not strain the working memory capacity of any adult.

Now consider the working memory required to multiply a two-digit number by a single digit, say 45 times 7. This problem, if solved in one's head, requires six steps, thus:

Step 1:

$$\begin{array}{r} 45 \\ \underline{\text{X } 7} \end{array}$$

Step 2:

$$\begin{array}{r} 45 \\ \underline{\text{X } 7} \\ \left(\begin{array}{r} 5 \\ \underline{\text{X } 7} \\ 35 \end{array}\right) \end{array}$$

Step 3:

$$\begin{array}{r} 45 \\ \underline{\text{X } 7} \\ 35 \end{array}$$

Step 4:

$$\begin{array}{r} 45 \\ \underline{\text{X } 7} \\ \underline{35} \\ \left(\begin{array}{r} 4 \\ \underline{\text{X } 7} \\ 28 \end{array}\right) \end{array}$$

Step 5:

$$\begin{array}{r} 35 \\ \underline{28} \end{array}$$

Step 6:

$$\begin{array}{r} 35 \\ \underline{+28} \\ 315 \end{array}$$

In the first step two memory registers are required, one for each of the problem numbers. In the second step the first multiplication has been performed and, temporarily, there are five numbers that must be remembered. Two of these numbers (5X7) can be discarded, leaving three numbers in the working memory in Step 3. In Step 4 the second multiplication occurs (4X7) and, briefly, there are six in memory. In Step 5 all the numbers except the two products can be forgotten, leaving a working memory load of two. In Step 6 the two numbers are shifted and added, leading to the answer. We can see in this example that the working memory load varied from two to six units. Since six is close to, but below, the average working memory capacity (7±2) we can predict that most people can solve the multiplication of 45 times 7 in their heads if they concentrate.

Now consider the problem of multiplying a two digit number by another two digit number (e.g., 69 X 56). Without working through the actual steps, an analysis reveals that three steps will require a working memory load of six items and one will require remembering seven items. Most people find that the mental multiplication of two numbers by two numbers is just at or a little beyond their capability. Note that the limit is clearly one of working memory capacity and not mental capacity. Given a pencil and paper the problem immediately becomes trivial since the paper substitutes for working memory registers.

Some people are very good at performing mental arithmetic. Their working memory is the same as that of everyone else; they simply group numbers and multiply according to different rules. By combining certain numbers, they rearrange the problems to avoid taxing their working memory beyond about six units. Indeed, combining or chunking to minimize working memory load is the real key to conceptualizing more and more complex problems.

For example, ten month old children are using several working memory units when they think about a dog. Simultaneous images and feelings about the dog and the potential interactions with the dog presumably all occur more or less together. The word "dog," however, chunks all these Sensorimotor images together and substitutes a single higher order image for a number of diverse visual and motor images. Thus, the working memory load is reduced to one unit--the word "dog." This in turn frees the child to think about other things and events since dog now requires only one memory unit.

Case has applied the concept of working memory capacity to several developmental studies, with interesting results. One study he has analyzed was originally conducted by Noelting (1974). Noelting showed children two large pitchers (A and B). Around each pitcher a number of glasses were grouped. Some of the glasses were filled with water while others contained orange juice. The experimenter explained that he is about to combine the glasses of water and orange juice by pouring them into the pitchers and that he wanted the child to predict which pitcher would taste the more strongly of orange juice. The child could count the glasses of each liquid that were to be poured into each pitcher, but could not actually pour the liquids. Figure 7 illustrates the problem, and the predictions made by children of various ages.

Noelting reports that the children used the following strategies:

> *Strategy I*. From 3 to 4-1/2 years of age the children evaluate the glasses in isolation, noticing only one global feature--the presence or absence of orange juice. If only one pitcher is to receive orange juice they can predict successfully, but otherwise they resort to guessing.
>
> *Strategy II*. Between 4-1/2 and 6 years children notice not only the presence or absence of juice on each side but also the quantity of juice. Thus their strategy becomes comparative. They succeed on all trials when the correct answer can be obtained by choosing the pitcher surrounded by the greater number of orange juice glasses.

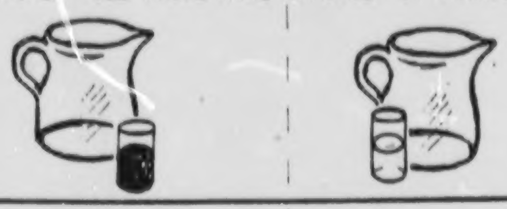
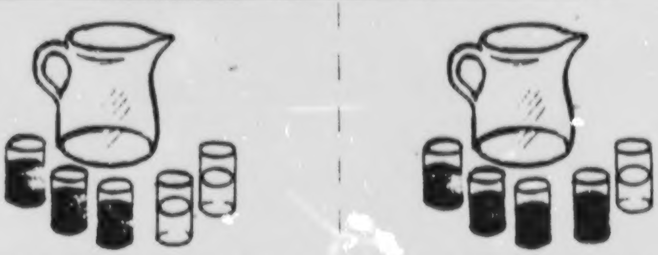
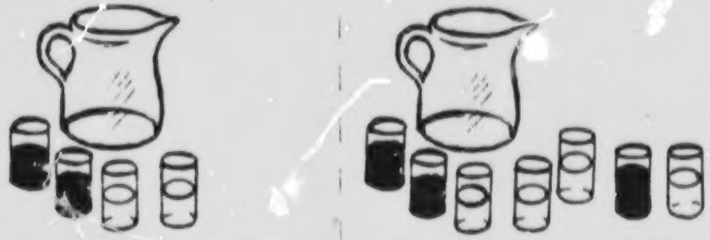
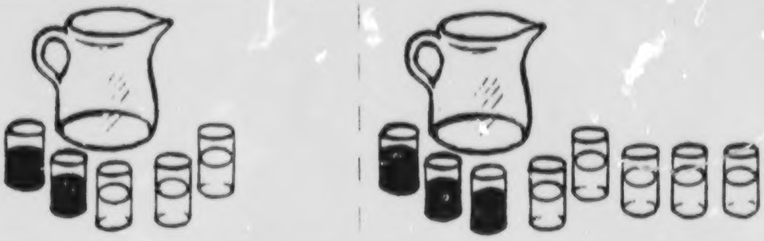
STRATEGY	AGE	TYPE OF ITEM PASSED	MEMORY LOAD
I	3-4	WHICH PITCHER WILL TASTE MORE STRONGLY OF ORANGE JUICE? 	1
II	4-5		2
III	7-8		3
IV	9-10		4

Figure 7. STRATEGIES OBSERVED IN NOELTING'S ORANGE JUICE PROBLEM (After Case, 1976a)

> *Strategy III*. Between 7 and 8 years the children notice the number of glasses of water by each pitcher as well as the number of juice glasses. They compare the number of glasses of water and juice on each side and select the side having an excess of juice over water. If both sides have more juice or more water or if both sides are equal, however, they simply guess.
>
> *Strategy IV*. Children who are 9 to 10 years old notice the extent of the excess or deficit of juice glasses over water glasses on each side. Thus, they succeed on any trial when the correct answer may be determined by deciding which side has the greater excess or lesser deficit. These children continue to fail, however, on items where an understanding of ratio is necessary.

Case notes that the working memory load required for Strategy I is one. Only the presence or absence of orange juice must be considered. For Strategy II, two items must be considered: (1) the number of orange juice glasses to be poured into pitcher A, and (2) the number of orange juice glasses to be poured into pitcher B. In Strategy III, three items must be considered: (1) the number of orange juice glasses near B, (2) the number of water glasses near B, and (3) the stored conclusion about the relative quantity of juice near A. Finally, Strategy IV requires consideration of four items, the additional item being the difference between orange juice and water glasses surrounding pitcher A. Note that these calculations are not based on the maximum number of items one could imagine, but rather on the total number of items the child *must* hold in working memory.

Case concludes his review of Noelting's study by saying: "Given that Noelting's sequence of strategies shows this progressively increasing demand on working memory, an obvious hypothesis is that the child's rate of progression through the sequence is determined not only by the quantity or quality of his specific experiences, but also by the rate of growth of his working memory" (Case, 1978). Case notes that a number of investigators have previously suggested that memory capacity plays a role in development, including Bruner (1966), Case (1968), Halford & MacDonald (in press), McLaughlin (1968), Pascual-Leone (1969) and Piaget (1928). Case, however, extends this hypothesis so that it plays a major role in explaining development. Although we will not pursue Case's theory much further, it is important to note how he explains the term, chunking. Case postulates that from a very early age children have four working memory units available. Only experience, however, enables them to develop their use. Thus, when a child completes the Sensorimotor Period at the age of 2, he or she is able to remember the *picture*, four simultaneous Sensorimotor action schemes in working memory. When the child enters the Preoperational Period these four action schemes are chunked into a single word, concept, or complex action. This leaves three memory units available for other uses. For awhile the child remains unaware of the existence of this newly acquired "Preoperational" memory capacity. Gradually, as illustrated by Noelting's study, the child learns to build models that once again take full advantage of his or her new working memory capacity. Case suggests that this same process is repeated during the Representational and the Formal Operations Periods.

Siegler's Encoding Capacity Model

Siegler has developed a hypothesis to explain the growth within a task (Siegler, 1976). In one study, for example, Siegler focuses on the ability of the child in the Representational Period to postulate and test rules. Siegler conducted experiments using a balance scale, as pictured in Figure 8.

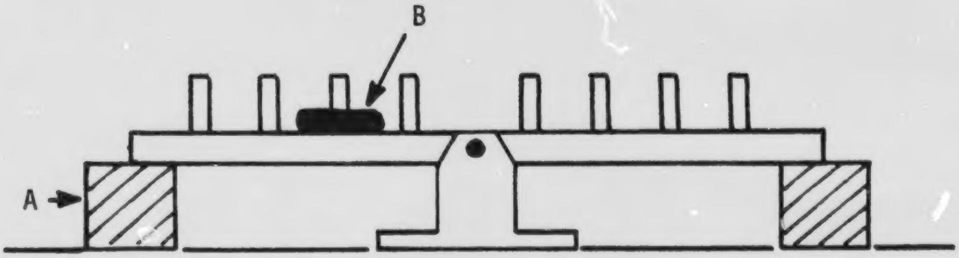
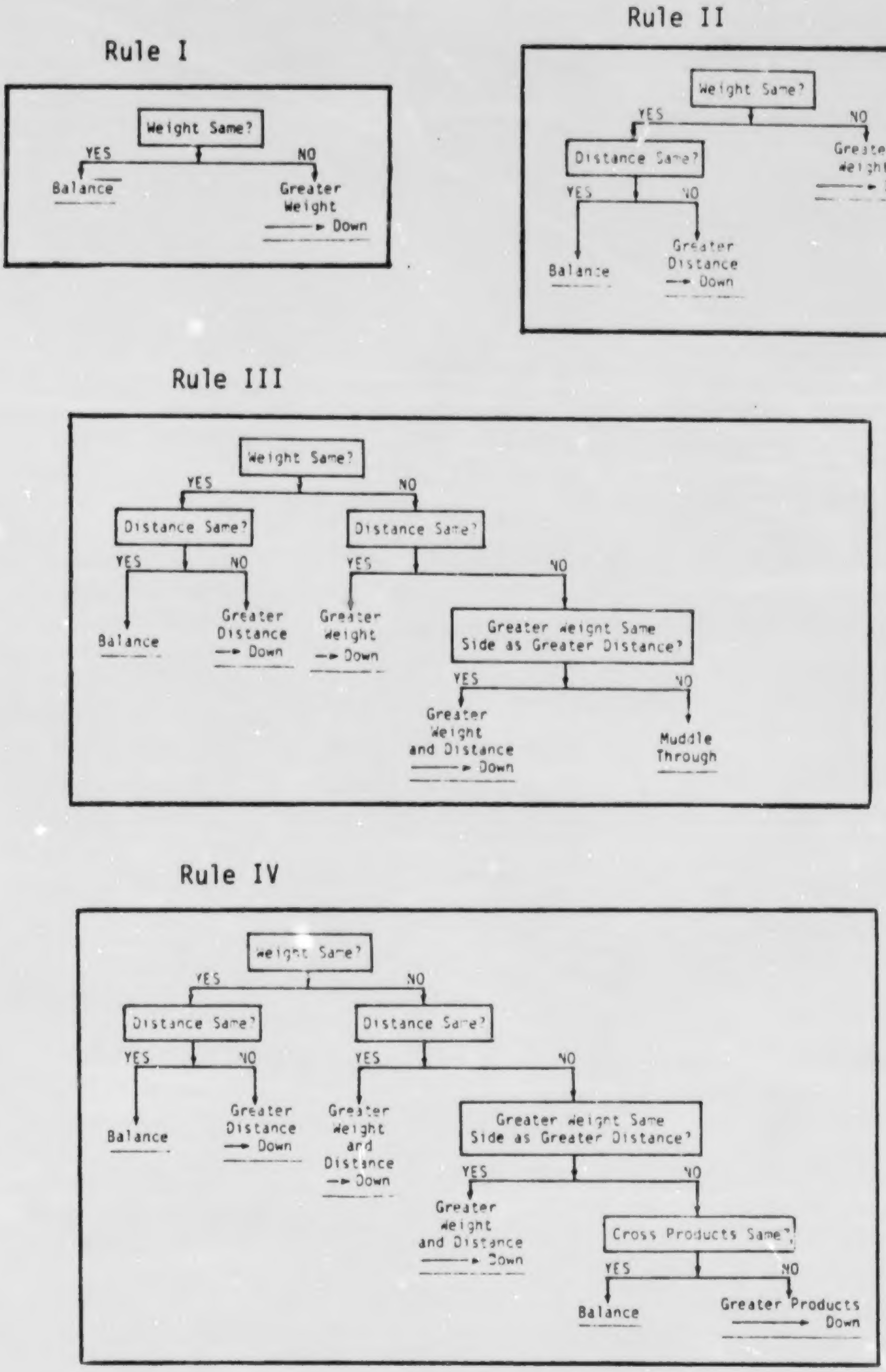


Figure 8. BALANCE SCALE USED BY SIEGLER

The balance is held motionless by blocks placed under the arms (A). Rings that serve as weights (B) are placed on the various upright posts and the child is asked to indicate which side would drop if the blocks were removed.

Siegler began with an analysis of the task. He postulated a decision-tree model of how a child might determine the solution to the problem. The complete tree involved four successive binary decisions. Siegler then divided the decision tree into four rules, each one involving an additional binary decision (see Figure 9). By examining errors, Siegler demonstrated that 5 to 6 year olds consistently used Rule I; 9 to 13 year olds used Rule III; and only some 16 to 17 year olds used Rule IV while most relied on Rule III. Furthermore, he found that experience helped older children who had been using simpler rules but that even direct instruction did not help younger children learn to use Rule IV. He concluded that being able to isolate and utilize one, two, three, and then four independent stimulus aspects of the problem was determined by maturation and that the upper limit of encoding capacity varied with age rather than experience. Thus, Siegler's approach to encoding capacity, although different, seems compatible with Case's hypothesis of working memory capacity.


Rule I

Rule II

Rule III

Rule IV

Weight Same?
YES
NO
Balance
Greater Weight → Down
Weight Same?
YES
NO
Distance Same?
Greater Weight → Down
YES
NO
Balance
Greater Distance → Down
Weight Same?
YES
NO
Distance Same?
Distance Same?
YES
NO
YES
NO
Balance
Greater Distance → Down
Greater Weight → Down
Greater Weight Same Side as Greater Distance?
YES
NO
Greater Weight and Distance → Down
Muddle Through
Weight Same?
YES
NO
Distance Same?
Distance Same?
YES
NO
YES
NO
Balance
Greater Distance → Down
Greater Weight and Distance → Down
Greater Weight Same Side as Greater Distance?
YES
NO
Greater Weight and Distance → Down
Cross Products Same?
YES
NO
Balance
Greater Products → Down

Figure 9. DECISION RULES NECESSARY TO DETERMINE WHICH SIDE OF THE BALANCE WILL DESCEND (After Siegler, 1976).

Fischer's Set-Theory Model

Fischer (in press) has recently proposed a Formal model of development based on set theoretic descriptions of seven successive stages.

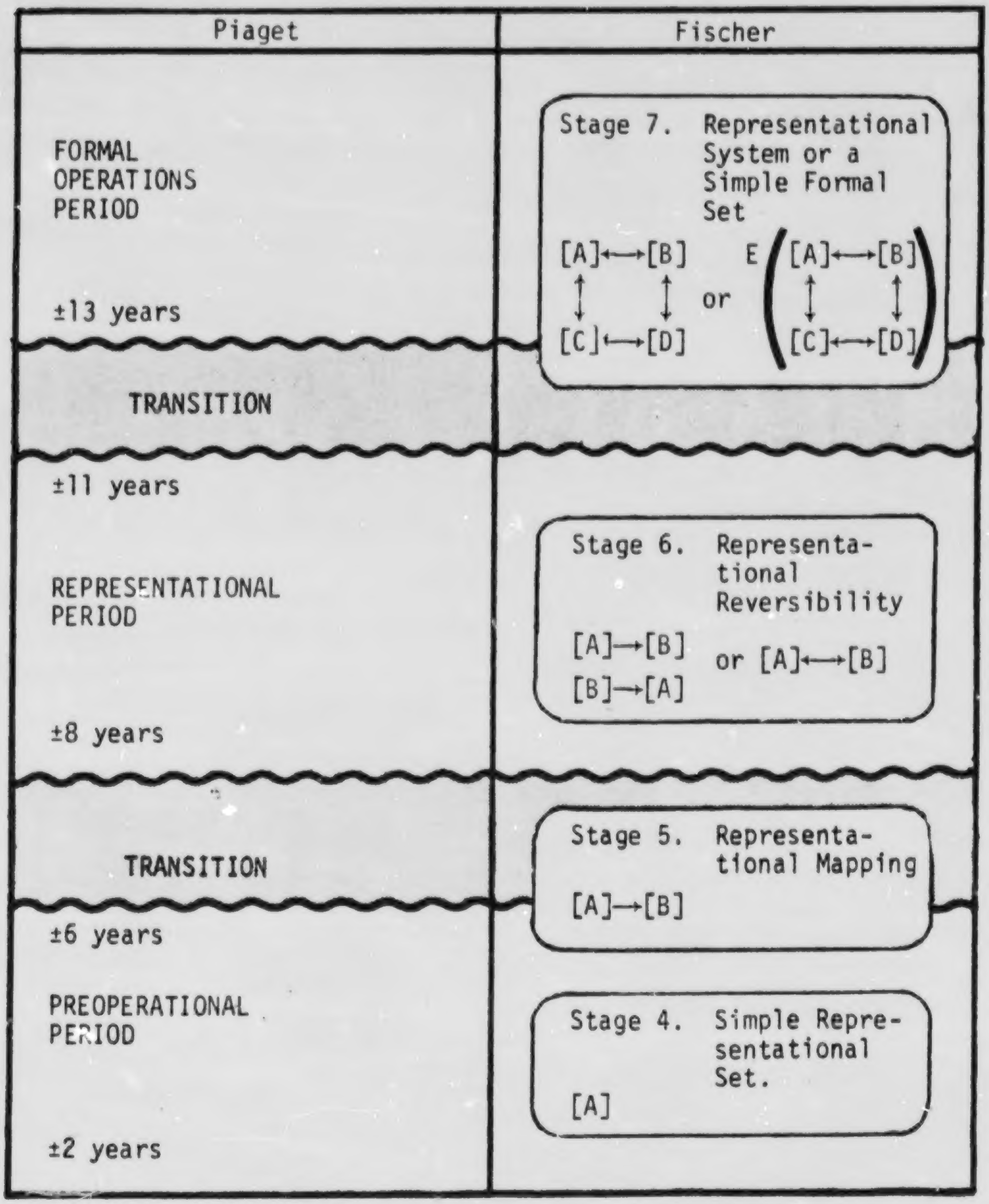

Piaget
Fischer
FORMAL OPERATIONS PERIOD
±13 years
TRANSITION
±11 years
REPRESENTATIONAL PERIOD
±8 years
TRANSITION
±6 years
PREOPERATIONAL PERIOD
±2 years
Stage 7. Representational System or a Simple Formal Set
[A]←→[B] [C]←→[D] or E ([A]←→[B] [C]←→[D])
Stage 6. Representational Reversibility
[A]→[B] [B]→[A] or [A]←→[B]
Stage 5. Representational Mapping
[A]→[B]
Stage 4. Simple Representational Set.
[A]

Figure 10. A COMPARISON OF PIAGET'S PERIODS AND FISCHER'S STAGES 4 THROUGH 7. (Note that we have altered Fischer's terminology to bring it more into line with Piaget.)

We briefly consider how each of Fischer's stages four through seven can be characterized.

Stage 4: Simple Representational Set. Fischer proposes that a simple concept is a set of Sensorimotor actions that have been chunked. Thus, a two year old who has many different stimilus-response interactions with the family dog, brings them all together in the word "dog." The word "dog" becomes a name for the entire collection of actions involving the family dog.

In Case's terms, the action of petting the dog's head, the action of being licked by the dog, the action of hanging onto the dog, etc., have been consolidated into the word "dog," thereby freeing other working memory units.

"dog" [
(dog's head → pat)
(dog → throw stick
(dog → get licked)
(dog's tail → tail wagged)
]

Figure 11. SEVERAL SENSORIMOTOR ACTIONS, IMAGES, OR COMPOUNDS GET CHUNKED INTO THE SIMPLE REPRESENTATIONAL SET--"DOG"

For our purposes we can start with a concept word representing a simple Representational set and designate it as Set A (See Figure 10). Note that the word "Representational" is used in Bruner's sense to indicate that the child represents the sensorimotor actions by means of a word--in our example, "dog."

Stage 5: Representational Mapping. At stage 5, the child maps one image onto another. Fischer represents this by inserting an arrow between two sets, thus (A)→(B). The word "mapping" is being used in a mathematical sense to indicate that Set A is equated to Set B, but not vice versa. Thus, for example, the child maps many dogs (A) (and perhaps cows as well) onto a single concept: "dog" (B). Mapping is a one-way process in which the child focuses on one image or concept and then understands that image or concept in the context of a second, more general concept (B).

Stage 6: Representational Reversibility. The transition to the Representational Period begins when the child begins to map sets onto one another frequently. Initially the child continues to move in one direction, thus: either (A)→(B) or (B)→(A). Finally, however, the images become reversible and the child can move back and forth freely. Fischer represents reversibility by a two-headed arrow, thus (A)↔(B).

The development of reversibility is a major event in the cognitive life of the child. With reversibility comes a sense of necessary relationships. The child who can move back and forth--or perhaps more accurately, the child who can hold (A) and (B) in his or her mind simultaneously, can begin to establish the exact relationship between the two sets.

Piaget's famous conservation of substance task is critical to understanding reversibility. The child pours the water from the normal glass to the tall thin container and is then asked to say if there was more water before or now. The child who is in Preoperations seemingly forgets the "before" state and maintains the tall thin container has more water. Once children acquire reversibility, however, they realize that the amount of water is the same, no matter what glass it is poured into. Having acquired reversibility, it is as if the children are capable of simultaneously picturing the images of two containers in their minds and pouring the water back and forth until they are convinced that the quantity of water is independent of the containers.

Representational reversibility also affects the child's sense of time. The child entering the Representational Period rapidly acquires a new sense of before and after. In Korzybski's terms, reversibility is the key to time-binding (Korzybski, 1958).

Stage 7: A Representational System or a Simple Formal Set.

Sometime around the age of eleven, another transition begins. Children begin to coordinate an increasing number of different but related Representational sets. They learn to develop hierarchies. For example, they learn to group large numbers of different kinds of dogs together and to subordinate this abstraction under more abstract characterizations such as "mammals" and "living things." Perhaps critical to the process, children learn to compare their concepts with those of others and to see the similarities. Fischer represents this complex coordination as four sets interconnected by two-way arrows, thus:

$$\begin{tikzcd}
{[A]} \arrow[r, leftrightarrow] \arrow[d, leftrightarrow] & {[B]} \arrow[d, leftrightarrow] \\
{[C]} \arrow[r, leftrightarrow] & {[D]}
\end{tikzcd}$$

Note that we could just as well include additional sets in this pattern.

At some point the adolescent begins to chunk the various concepts into a single higher order concept or Formal set. In effect the child looks back and forth between images until a common element is found. This allows students to chunk Representational concepts together into a single Formal or abstract concept. Fischer represents a simple Formal set as:

$$^{E}\left[\begin{tikzcd} {[A]} \arrow[r, leftrightarrow] \arrow[d, leftrightarrow] & {[B]} \arrow[d, leftrightarrow] \\ {[C]} \arrow[r, leftrightarrow] & {[D]} \end{tikzcd}\right] \quad \text{or} \quad [E]$$

In arriving at a simple Representational set, the child "chunks" a collection of Sensorimotor memories into a single image that can be held in mind even if the object that occasioned the action is absent. Note, however, that this image is a set of Sensorimotor memories and is thus always tied to objects in the child's environment. Throughout the Preoperational and Representational years, Piaget shows that the child must think in terms of images derived from reality. Children may distort their images in various ways but they do not hypothesize images that have no roots in actual experience.

In arriving at the simple Formal set children move beyond Concrete concepts and begin to conceive intangible functions and relationships. These functions or relationships do not exist as images available to observation. Instead, they exist as symbols that represent ongoing patterns of interaction.

In Siegler's study, older children learned to use Rule III to systematically solve all possible balance beam configurations except those involving ratio or porportion (the cross products). Children who use Rule III can observe all of the elements necessary to make the appropriate decision. To use Rule IV, however, children must cross multiply, thereby creating an intangible ratio. They must then assume that the side with the greater product will be the side that will descend if the blocks are removed. In other words, the adolescent must conceptualize the problem in terms of an abstract relationship that can not be observed.

In Case's terms, we might suggest that during the transition between the Concrete and Formal periods, the child is forced to entertain four diverse collections of reciprocal relationships between images, each occupying one of four working memory units. After the transition, the child manages to find an invisible but consistent higher order relationship that only occupies one working memory unit.

Thus, Fischer's proposal of a repetitive pattern of coordination between different types of remembered sets is parallel to Case's estimation of the working memory load required to solve the problems typical of Piaget's successive periods. At the same time, since Fischer's definitions are Formal, they provide a convenient and simplified description of the Piagetian model. We will rely on Fischer's set theoretic model throughout the latter sections of this monograph to describe various problems.

Social Role-Taking and Moral Judgment

Developmentalists have also studied the relationship between cognitive development and moral and social development. From the beginning this research has been complicated by the necessity to discriminate between what children say they would or should do and what, in fact, they actually do.

Piaget initiated developmental studies into moral development by studying the game-playing behavior of Swiss school Children (Piaget, 1932). Piaget asked children about the rules they observed and the fairness of those rules. He also presented children with stories in which two actions and their consequences were pitted one against the other. Children were asked to judge which of the two was the more serious moral infraction. Based on these studies, Piaget proposed that there were stages of moral development which corresponded with his cognitive developmental periods.

The first researcher to follow Piaget in this area was Kohlberg (1976). He investigated moral judgment by means of questions asked about moral dilemmas. On the basis of the answers, Kohlberg postulated six levels of moral reasoning. Kohlberg's technique considerably confused the distinction between saying and doing, and his work has not been reliably replicated.

Recently three investigators have attempted to make some sense of this confusing domain. Turiel (1975) began by distinguishing between moral and conventional reasoning. A conventional rule is one that serves a social regulatory function such as a dress code or a form of greeting. A moral rule is a more abstract principle, such as fairness or reciprocity. Where Kohlberg posits that children mistake moral decisions for conventional decisions, Turiel explores the two domains separately. Like Piaget and Kohlberg, Turiel employs hypothetical stories and interviews to gather data. Turiel's results, while mostly confined to young children, justify the distinction between moral and conventional rules.

Selman (1976), working in the information processing tradition, has studied the ability of the child to take the role or perspective of other persons. Selman's work seems important, but unfortunately he has not studied older students.

The most recent, and perhaps the most promising work, is that of Damon (1977). His work in social cognition avoids the obvious methodological problems raised by Piaget, Kohlberg, Turiel, and Selman. Damon, like Piaget, investigates language behavior as well as actual social interactions in natural settings. Damon is interested in natural settings and in identifying successive stages of social understanding, just as Kohlberg is, but he is careful to examine the transitions between stages and to distinguish between moral and conventional themes. He integrates his findings with those of Selman. Unfortunately Damon's studies are also confined to young children.

We have summarized the findings of each of these investigators in Appendix A. We will not go into more detail here since the findings to date have little to say to educators working with grade school, high school, or college students.

We can summarize the subject of social role-taking and moral judgment briefly. The latest research, while encouraging, is so far confined to younger children. The findings indicate that moral reasoning lags behind cognitive development, but follows the same general pattern. The findings are too weak, however, to allow us to suggest practical applications at this time.

DEVELOPMENTAL PERIODS UPON WHICH TO FOCUS ATTENTION

We assume environmental educators are concerned with children in grade school, with older students, and with adults. Thus, we will now turn from a general consideration of the developmental sequence to a more detailed consideration of the periods that encompass this age range: the Representational Period, the transition between the Representational and the Formal Operations Period, and the Formal Operations Period.

The Representational Period

Although the initial and final ages vary considerably, most children are clearly in the Representational Period throughout their elementary school years. Moreover, a considerable number of high school students, college students, and adults think predominantly in the Representational mode (Renner, et al., 1976).

Piaget refers to the period that extends from about two years to somewhere between eleven and thirteen years as the period of Concrete Operations. He then subdivides the period into a Preoperational Period (±2 to ±7 years) and another Concrete Operations Subperiod (±8 to ±11 years). This seems unnecessarily complex. Moreover, recent studies have strongly indicated that many college students and adults function primarily in the Representational mode throughout life. We have avoided the term "Concrete" because it involves an image of undue inflexibility. The term "Representational" was first used by Bruner as a synonym for Concrete and we have also elected to use that term. For the purpose of this monograph, the Representational Period begins at about seven years of age (after the Preoperational Period) and extends until the individual enters Formal Operations.

Bruner chose the word "Representational" and Piaget chose the term "Concrete Operations" to stress that the individual in this period conceptualizes the world in terms of specific, real images. The individual gradually develops the ability to manipulate these Concrete images in a variety of sophisticated ways, but never "hypothesizes" objects that he or she has not really encountered at one time or another. The Representational thinker cannot adequately use concept words that refer to such invisible things as "ratio," "proportion," "energy," or "ego strength." The ability to use functions, hypothetical constructs, complex literary metaphors, and meta-languages must wait until the individual enters the Formal Operations Period--which begins during high school or college.

Bruner has stressed the role of memory in this entire process (Bruner, 1964). He proposes that the individual in the Concrete Period constructs and manipulates models of the world by means of specific, real images. In other words, the individual mentally represents real objects--hence, the term "Representational." (In contrast, Bruner believes the Formal individual remembers and models the world by means of more abstract symbols.)

The Representational Period begins at approximately seven years of age for most children. At this age the child is typically able to conceptualize a set (i.e., place a boundary on a problem situation) but not with flexible criteria. Such a child, given a specific rule, could develop a set. For example, a child is asked to sort a set of large and small, red and blue blocks. A child in the Representational Period could sort the blocks--perhaps with the criterion of color. If the child is asked to regroup the blocks "in some other way," this will be difficult--especially in the early years of the Representational Period. The child would not be able to pick a new criteria by which to proceed. The child's criterion is arbitrary, yet fixed. However, if asked to pick up all of the large blocks and put them in one box, the child could do it. In other words, the child has acquired what Gagné calls Concrete concepts. He or she can identify every large block, and can exclude every small block. This accomplishment can be demonstrated when the instructor clearly defines the task. The child focuses on one characteristic and the output or desired result and proceeds to perform correctly. The child can not, however, establish two consistent, independent classes. In effect, he or she can not restate an original rule for the division of the blocks and then proceed to implement that rule.

The development of the Representational capacity accelerates as children develop their own simple rules. Indeed, many have characterized the entire Representational Period by calling it a period of rule making. In the social area, which we will treat in greater detail later, the beginning of the Representational Period is marked by the beginning of an ability in children to participate in games that have a commonly agreed upon set of rules.

The early Representational years, from six to eight, are marked by the child's increasing ability to develop rules. The rules developed during this period tend to be rules involving a single attribute or variable. Thus, for example, the child establishes consistent rules to judge amounts of fluid. If two containers are compared, it is one in which the fluid is higher that has more. This approach is used regardless of the shape of the containers.

Fischer notates this as $[A] \longmapsto [B]$ (or $[B] \longmapsto [A]$). Case speaks of it as "unidimensional comparison," arguing that it indicates that the child can handle a working memory load of only one Representational unit at a time. It is as if the child has one clear image or model of a desired outcome--say, a tall column of fluid--and each successive instance is matched to that sample to determine if it is a proper member of the set.

In Siegler's terms, the child makes one binary decision. In the case of the balance beam, the child asks only: "Are the number of rings on each side of the balance the same?" The child rule apparently says that whichever side has the most rings will drop when the blocks are removed. Obviously, if one side clearly has more rings and they are equidistant from the center this prediction will be accurate. If the number of rings on both sides is equally balanced but the rings are spaced at different distances from the fulcrum, the children resort to guessing. This illustrates two points:

(1) The child is using a simple, one variable rule. The child's model of the problem includes the assumption that one side of the balance will fall and that he or she is to indicate which it will be. The model is not fully specified. The child is only considering one element or variable in the situation which has other essential variables.

(2) This single-variable rule or model does, in fact work in some situations. It may even be that the rule works in most of the real world situations. In other words, the child's approach is not entirely wrong. It should be viewed as a first step or approximation of the Representational Period--the initiation of rule making and, thus, of self-generated problem analysis and prediction.

At about seven or eight years of age, the child typically reaches the crux of the Representational Period and, when successfully mastered, he or she displays what Piaget calls "reversibility." This means that the child can consider two variables simultaneously. This, in turn, means that he or she can simultaneously conceptualize the "before" and "after" states of a problem and compare them. It is at this point that a child realizes that both the ball of clay and the sausage into which it is transformed must contain the same amount of substance. Presumably the child can picture (i.e., represent in the "mind's eye") both the ball and the sausage and flip them back and forth until he or she is convinced that the amount of clay must be constant. Once the child acquires reversibility on any one problem, the idea generalizes rapidly to other problems (see Figure 12).

Case argues that reversibility occurs when the child can handle a working memory load of two units. He refers to it as "bidimensional comparison." Fischer represents reversibility as [A]⟷[B]. Siegler notes that about this same time the child begins to develop rules that depend upon two independent decisions. Thus, in the balance problems, the child now observes both the relative amount of weight and relative distance of the weight from the fulcrum. The clear implication is that once the child acquires reversibility he or she can model a situation that displays temporal or causal relationships. Indeed, the real beginning of the use of rules to make predications begins with reversibility.

Before the child acquires reversibility, he or she can sort on a single criteria without being fully able to understand a temporal sequence. Thus, for example, the child cannot say words to the effect that "the ball and the sausage of clay must be the same because the latter is just the substance of the former after you rolled it out." Before reversibility the child observes the ball, then the transformation, and then the sausage. When asked a question the child answers as if the events preceding the sausage had not occurred or were irrelevant (even though he or she can describe the events if asked). Before reversibility the child can make and use only rules involving matching a specific instance to an archetype; after reversibility has been achieved, he or she can model two concepts and their transformation (See Figure 12).

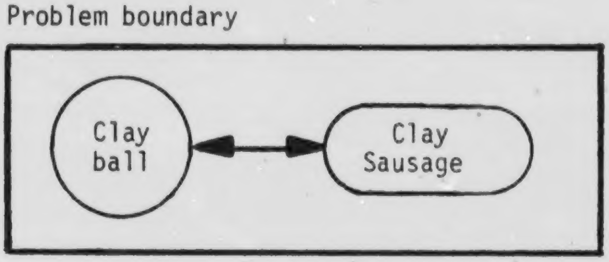


Figure 12. HYPOTHETICAL MODEL OF CONSERVATION OF SUBSTANCE PROBLEM

The later years of the Representational Period, from eleven to adulthood, involve an elaboration on the number of specific variables and transformations the student can model or make rules about. In all cases, as long as the individual is in the Representational Period, these variables are real, concrete, or substantive things. The student learns to build models of anything he or she can see or has seen, and to make predictions about any outcomes previously observed. Until Formal Operations begin, however, the student's models are devoid of variables that involve abstract concepts such as ratio, proportion, or volume.

By the age of nine or ten, for example, the child can normally model three concrete variables. By ten to twelve years many children can deal with rules involving four or five variables. Thoughout this same period the child acquires a knowledge of elementary mathematics and thus can increasingly use rules that involve quantification. At the same time, the child's ability to analyze problem situations and to isolate variables increases. At age nine, for example, the child could easily divide the blocks we mentioned earlier into two classes (e.g., red and blue) and then redivide them into two other classes (e.g., large and small). The child can easily assign his or her own rules for sorting and can easily shift from one rule to another.

By eleven to thirteen years of age, most students become capable of not only relating about four variables, but of comparing one such Concrete model with another. In other words, they develop the ability to think about problems by coordinating one Concrete situation with another.

A study by Winner, Rosenstiel, and Gardner (Winner, et al., 1976) on the development of metaphoric understanding provides a nice example. The experimenters worked with two general types of metaphors:

- Metaphors comparing a psychological system and a physical system--e.g., "After many years of working at the jail, the prison guard had become a hard rock that could not be moved," and
- Metaphors comparing one sensory system with another--e.g., "The smell of my mother's perfume was bright sunshine."

To analyze children's answers, Winner, et al. found it necessary to identify four different types of "metaphors" (See Table 2). The experimenters classified children according to the way they explained the initial metaphors. It was found that six to seven year old children used either magical, metonymic, or primitive metaphors, or they failed to produce an adequate metaphor. At eight to ten, children typically used either primitive metaphors or genuine metaphors, while by fourteen almost all of the children studied were using genuine metaphors. Interpreting this broadly, we can say that

Type of Metaphor	Example	Denintion and Guidlines for Scoring
Magical	The king had a magic rock and he turned the guard into another rock. Her perfume was made out of rays from the sun.	A paraphrase is offered that maintains the literal meaning of the sentence. Plausibility is achieved by inventing a magical world in which the laws of the natural world do not apply.
Metonymic	The guard worked in a prison that had hard rock walls. When she was standing outside in the bright sun she was wearing perfume.	The sentence is rephrased so that the two terms of the metaphor can both be interpreted literally without defying realism. Plausibility is achieved by relating the two terms through contiguity rather than through identity.
Primitive Metaphoric	The guard had hard, tough muscles. Her perfume was a bright yellow color like the color of the sun.	Through a focus on an incidental aspect of the first term, the dual-function adjective retains its primary meaning in the modification of both terms of the metaphor. No comparison is made between the physical and psychological domains or between the sensory modalities.
Genuine Metaphoric	The guard was mean and did not care about the feelings of the prisoners. Her perfume had a wonderful smell.	A central aspect of the first term is noted; the dual-function adjective thus achieves its secondary meaning in the modification of both terms of the metaphor. An implicit comparison is accordingly effected between the physical and psychological or between two sensory modalities.

Table 1. LEVELS OF METAPHOR USAGE (After Winner, et al., 1976).

at the beginning of the Representational Period the children reinterpreted metaphors so that they became literal statements about single systems. In other words, the metaphors were changed into the terms of one sense modality (one-way mapping) or they were made into statements about the physical prison system. By the middle of the Representational Period, the explanation took both terms of the metaphor into account, but confined the explanation to a single term. At the end of the Representational Period, or, in fact, at the beginning of the Formal Operations Period, the children were able to consider each of the two metaphorical terms being compared independently and to explain why they were being compared. In other words, they could explain the abstract relationship that held the two terms together in the metaphor. Winner, et al. concludes:

> Taken together with results of prior research on metaphor, these findings suggest that spontaneous production occurs first, followed by comprehension and then by the ability to explain the rationale of a metaphor. The spontaneous metaphors produced by young children are most often visual comparisons promoted by stimuli in the environment. In contrast, the comprehension of another's metaphor typically demands not only that both terms be imagined but also that properties other than perceptual ones be taken into account. Finally, the ability to explicate the workings of a metaphor involves a distance from the processes of both metaphoric production and comprehension as well as that metalinguistic awareness that only arises in preadolescence (Winner, et al., 1976).

Thus, to summarize: advanced Representational students are typified by the skillful use of imagery and all those aspects of language and symbolization that are referential in nature. An individual capable of Representational thought can think and plan effectively about the properties and relationships of objects which can be seen and touched. Most of us funtion more or less at the level of advanced Representational thought as we live our daily lives. We interact with the specific environment in which we find ourselves in ways that have a long history of success.

The Transition from the Representational to the Formal Period

Piaget has always argued that the transition between one period and the next occurs more or less instantaneously. It is as if the child suddenly becomes overwhelmed with the contradictions and difficulties of his or her model and creates a new, more adequate model. The entire process, again, reminds us of a Kuhnian paradigm shift, with the emphasis on the sudden insight that a scientist has when he or she shifts to a new paradigm. We imagine the child somewhat like Copernicus, suddenly wondering: "What if I rearranged the data on the assumption that the sun and not the earth was the center of the solar system?"*

One must be careful to discriminate between two contexts in which "transitional period" is used. In other parts of the monograph (cf. figures in Appendix A), we have used wide bands to suggest that transitions occur over months or even years. In that context we are describing the child population as a whole, not individuals. With the transition from Representational to Formal thought, for example, we are saying that some begin as early as age eleven; others as late as thirteen or later (hence, 13+). Our charts show the transition at the aggregate level, which is quite relevant to education and curriculum planning.

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*Although there is no demonstrated connection, as yet, a new field of mathematical model building, commonly called catastrophy theory, offers a possible explanation of how a long series of discrete experiences might result in an instantaneous, quantum change in the student's ability to solve problems. Developmentalists are already exploring the possibilities of applying catastrophy theory in analyzing Piagetian stage transitions. (For further information on this interesting type of modeling, see: Thom, 1975; Zeeman, 1976; and Saari, 1977.)

In this context, we are concerned with the transition interval for an individual regardless of the time of onset. Piaget's claim is that each child will move rapidly from one period to another. He makes no such claim about the group.

The best evidence for a sharp transition is the rapid shift from the Sensorimotor to the Preoperational Period and there is still a relatively quick change found between the Preoperational and the Representational Period. It is much less clear, however, that the shift from the Representational Period to the Formal Period occurs quickly. Indeed, the data can easily be interpreted to indicate that a gradual shift occurs.

Piaget and others have somewhat obscured this issue by creating an early Formal Subperiod that could just as easily be interpreted as a broad transition period. More important, although Piaget has suggested that children tend to make the transition to Formal Operations between the ages of eleven and thirteen years, researchers have discovered that large numbers of adults have not made the transition at all. Renner, for example, studied college students and found that, depending upon the college, from 40% to 80% of the students were Representational rather than Formal (Renner, et al., 1976). Studies by the other researchers have suggested that whole cultures or subcultures remain predominantly Representational (LeVine, 1970). Indeed, many have used this evidence to suggest that there is no natural progression from Representational to Formal and that the shift is simply a matter of accumulating experience at dealing with Formal problems. The counter argument, of course, is that in good schools children do, in fact, seem to make a transition from a Representational way of viewing the world to a Formal way of conceptualizing it. Other studies seem to support the idea that most adults are capable of Formal Operations in situations with which they are familiar, but that they readily fall back to Representational modes of functioning when confronting new situations.

We believe that, as a practical matter, curriculum designers and instructors working with high school, college, and adult students should initially assume that the students are in the Representational Period and design exercises to teach effectively at the Representational level while adding additional materials to encourage a shift from Representational to Formal.

A number of researchers have considered how to encourage the transition to Formal Operations. Remember that in Fischer's notation, we are dealing with the following situation:

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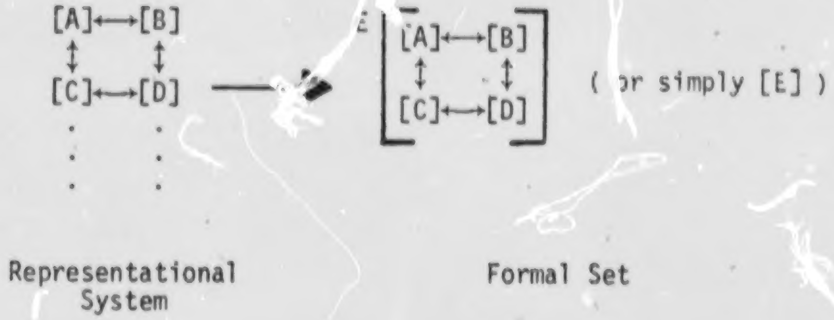

The Representational level is able to conceptualize a large number of sets and their interrelationships but has not yet learned how to chunk them into a single, abstract set. For example, the student may understand a large number of relationships regarding the balance, fulcrum, and placement of the weights, but not yet have the Formal concept of ratio (i.e. cross products).

Consider a social example of the transition process. "Mother" is a concept that has strong Sensorimotor, Preoperational, and Representational roots. In the early Preoperational Period children will sometimes get involved in arguments, each maintaining that his or her mother is the "real" mother. At some point during the Preoperational Period, however, children learn that all children have mothers, but they each continue to regard their own mother as having a whole set of special and unique characteristics. By the time most youth reach adolescence, they are typically engaged in a more or less tense identity struggle with their parents. One hears them say, "My mother doesn't understand; she said...." Or "My mother is really messed-up; yesterday she...." etc. In effect, we suggest that while, on some rational level, adolescents are quick to agree that we all have mothers, they still hold egocentric and Representational concepts of their own mothers. Their mother and their relationship with their mother is uniquely difficult. This seems to change only as the youth talks with peers and with adult friends. Gradually "mother" becomes a Formal concept. "Mother" is the name of a role; the role has been defined by a history of interactions and it prescribes relationships. The youth finally learns that during the struggle for identity all parents are perceived to be difficult to get along with, irrational, and overly worrisome. All mothers remember to ask their children about things the children would rather forget: "Do you always have to bring that up, mother? I haven't forgotten my wallet in years now!"

All this illustrates the idea that by acquiring other people's perspectives and coordinating them, we develop Formal concepts. We free ourselves from the image-dominance of the Representational Period and develop those more abstract concepts that finally allow us to conceptualize our parents as real, unique people who are only incidentally our parents. This is not to say that they cease to be our parents. The Sensorimotor, Preoperational, and Representational modes of thought persist. But gradually they are integrated into a broader perspective that also includes the abstract concepts that "mothers will be mothers" and that "we all act a little different when we interact with our parents."

Piaget has consistently maintained that the major stimulus or driving force behind the transition from the Representational Period to the Formal Operations Period is social interaction. He suggests that peers help to increase the complexity of a student's Representational systems until the student learns to use Formal models. This, of course, sounds very similar to what a learning theorist would say without making any developmental assumptions. Suffice it to say that the dynamics behind the transition are not completely understood but that they seem to involve practice with problems that can be modeled either as a Representational System or a Formal Set. Moreover, we should not necessarily assume that high school students, college students, or adults have made the transition, especially when they are confronted with a situation with which they are not familiar.

The Formal Operations Period

Formal thought is characterized by the ability to entertain abstract or Formal hypotheses, to control variables in order to test hypotheses, and to reflect upon concepts and principles for which no Concrete representation is available or possible. Phillips (1975) describes Formal Operations as "operations upon operations."

Two well-known Piagetian tests of Formal Operational thought are (1) the Sinking and Floating Task and (2) the Colorless Chemicals Task*. Students at the Representational level can correctly predict that a number of items will sink or float but lack a universal understanding that facilitates predictions in any and all cases. They can not formulate the concept of density since they can not conceptualize a variable that is not open to direct observation. Density is the ratio of an object's weight to its volume. And while both volume and weight can be observed, the relationship between them is a Formal abstraction that must be hypothesized in some symbolic sense. Thus, a successful solution of the Sinking and Floating Task illustrates one of the major characteristics of Formal thought--the ability to conceptualize abstract, invisible variables.

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*Each is analyzed in more detail in Appendix A.

The Colorless Chemicals Task requires the student to mix different combinations of four colorless chemicals to determine which combinations will result in a solution that turns a bright color. Students at the Representational level will try many different combinations and, in some cases, they will arrive at one of the possible solutions, but they are never sure that they have found all of the possible solutions to the task. Students capable of Formal Operations will systematically explore all of the possible combinations. In other words, they begin by conceptualizing an approach that will explore each and every hypothetical possibility. And, because they know that they have explored every possibility, they can answer with certainty that they have found all possible solutions to the problem.

These tasks, as well as numerous other Piagetian tasks, can be rather generally summarized as follows:

- *Formal operators can control variables in an experimental design to isolate a cause.*

  Several "formal" tasks require the subject to demonstrate and explain how to control variables in a problem situation so as to determine which of two or more variables is the cause of a particular phenomenon.

- *Formal operators can identify and abstract a pattern and use their knowledge of that pattern to be systematic in solving some problem.*

  In these tasks the subject is asked to predict which combinations of some set of units will result in some particular phenomenon. The student is successful if he or she recognizes an abstract, symbolic, or mathematical pattern that allows the prediction of all possible outcomes. This recognition is demonstrated when the student carries out an experiment guided by a formal pattern and is later able to assure the experimenter that all possible variations have been examined and therefore the subject is sure the results are complete.

Consider another task: discovering how to predict the actions of a balance beam scale. With an apparatus like that used by Siegler (cf. Figure 8), one asks a subject to experiment and find out when and why the beam will balance. The two variables are weight and distance--each measured on ratio scales.

The Representational student will begin by testing different combinations of weight and length in no particular order. As the beam balances or tips, the subject's explanation includes attention to one variable or the other--but not to the interaction of both. These responses correlate with Rules I to III (cf. Figure 9).

The Formal Operator will hold something constant; in this case, the weight and length arrangement on one side of the beam. Ultimately, the Formal Operational subject will develop an explanation that involves comparing the relationship between weight and length on one side of the balance with the weight-length relationship on the other side.

Representational students begin with an instance and try to imagine another possibility. Formal thinkers begin by recognizing a particular instance as an example of some class of similar situations and then use what they know about the class in general to predict a number of different possibilities relative to the particular situation.

To use a diagrammatic explanation, a Representational student might examine a particular classification matrix pattern (as in Figure 13) and come up with a new variety (b), but he or she would not immediately see that "purple, large" was not only a particular thing, but also an instance of a matrix interaction and thus also the representative of a column of possibilities as illustrated in (c). This can be summed up by saying that a Representational student always begins with a given problem and seeks to imagine something to add to it. By contrast, the Formal student begins with an abstract model or set of variables and considers what actually exists at the moment as well as what other possibilities are latent in the particular situation. And, of course, those latent possibilities are derived from the Formal Operator's recognition of the abstract model or pattern that the particular problem only typifies or concretizes.

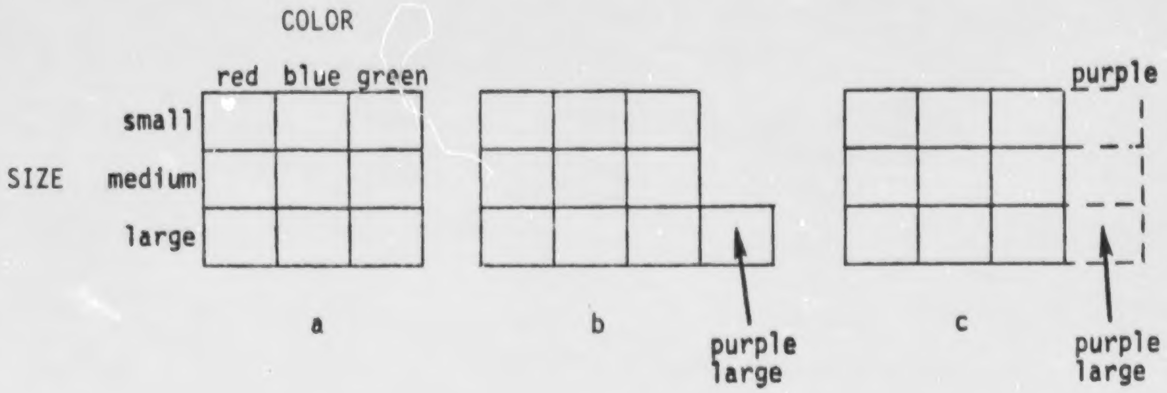
COLOR
red
blue
green
SIZE
small
medium
large
a
b
purple
large
purple
c
purple
large

Figure 13. THE ADDITION OF CONCEPTUAL SPACE BY A REPRESENTATIONAL THINKER (b) AND BY A FORMAL THINKER (c)

Another way of conceptualizing the distinction between Representational and Formal thought is to imagine a driver in a car passing another car on a curving road. (See Figure 14.)

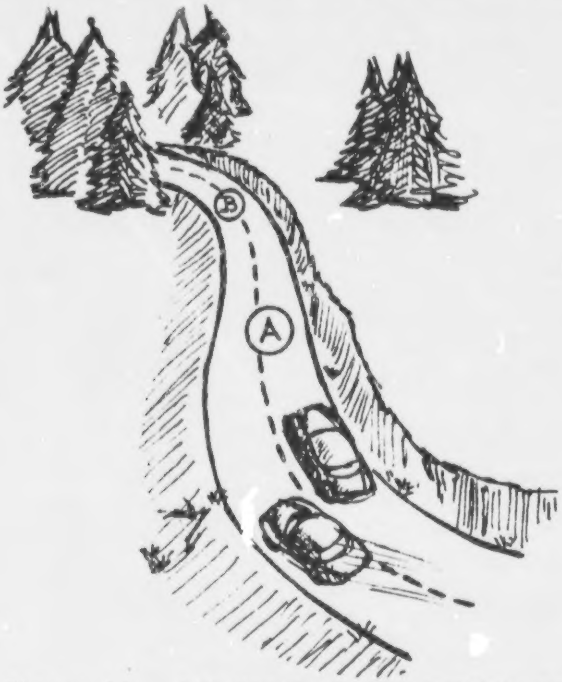

Figure 14. CAR PASSING ON A CURVING ROAD

Assume that when the driver pulls out to pass, he or she expects to be safely back on the right side of the road by the point marked Ⓐ. If that occurs, then the passing decision will have been a safe decision, for even if an oncoming car rounds the bend just as passing begins, the pass will have been complete before such an oncoming car would reach point Ⓐ. If, on the other hand, even with skill and the maximum possible acceleration the passing car fails to regain the right lane before point Ⓑ, then the possibility of a collision will have occurred. In this second case, if a car had rounded the turn when the passing car was parallel to the car being passed, a head-on collision would be likely.

Now assume that the driver of the passing car was a teenager who managed to regain the right lane by point Ⓑ without encountering any oncoming traffic. What conclusion might this individual draw about his or her decision to pass? If the driver were a Representational thinker he or she would probably decide that the decision was correct. The Concrete evidence of a successful pass would seem to prove that it could be done. If the driver were a Formal thinker, however, he or she would realize that the pass was a potential failure. Such a driver might think: "I thought if I accelerated fast I could get back in by Ⓐ, but in fact I could not. I guess I'm lucky there was no oncoming traffic. I surely will not make a mistake like that again."

This example suggests why there can be a burst of learning following the transition from Representational to Formal thought. The Representational student only learns one thing from the experience of passing. The Formal thinker can consider many different abstract, alternate possible outcomes and thereby can learn many different lessons from the same specific experience.

Piaget identifies eight types of Formal concepts, the manipulation of which require Formal Operational thought (Inhelder & Piaget, 1958). These have been nicely summarized by Neimark, roughly as follows (Neimark, 1975).

(1) *Combinatorial operations:* General, systematic procedures for generating all possible distinguishable pairs of n x (combinations) or all possible orderings on n x (permutations).

(2) *Proportions:* The ability to deal with the equality of two ratios (x/y = x'/y'), as in operating balance equipment or in solving an equation.

(3) *Coordination of two systems of reference:* The ability to coordinate two or more disparate referential systems that underlies all relativistic thinking.

(4) *The concept of mechanical equilibrium:* The principle of the equality of action and reaction. (Closely related to (2) above.)

(5) *The concept of probability:* Probability is defined as a proportion, the numerator and denominator of which generally require calculation of combinations. (Presupposes both (1) and (2) above.)

(6) *The concept of correlation:* An extension of the notion of probability as defined in (5) above.

(7) *Multiplicative compensations:* The coordination of three variables, as, for example, problems involving the conservation of volume which itself is a thing having three dimensions.

(8) *Forms of conservation* that go beyond direct empirical discovery or verification, including, for example: inertia, energy, and valence.

Fischer, as we have already noted, believes that Formal Operations constitutes the chunking of a coordinated system of Representational sets, probably specific images, into a single Formal set that is best conceptualized as some kind of symbolic image. Case believes that when the students complete the transition from the Representational Period to the Formal Operations Period, they have moved from a working memory capacity of four simultaneous Representational images to a working memory capacity of one symbolic image. Thus, implicitly at least, Case suggests that when students begin Formal Operations, they begin another loop of a spiral that will conclude when they can conceptualize models involving the simultaneous interactions or variations of four or five symbolic images.*

In terms of the work of Winner, et al. (1976), the Formal Operator is able to understand and produce genuine metaphors. This, in effect, means that the Formal students are capable of conceptualizing how a particular sentence or phrase (or in the case of a pun, a single word) can simultaneously belong to two different sets and thus have two different meanings. Indeed, since students are able to comprehend the metaphor, they are able to conceptualize the Formal way in which the metaphor combines the two essentially unlike sets into a higher unity. In this sense metaphors represent literary variables.

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*We have briefly speculated on the possiblity of adult periods beyond Formal Operations in Appendix B.

Piaget (1956) has claimed that peer interaction is important in facilitating the transition to Formal Operations. He suggests that students expand their perspective as they come into contact with the varying perspectives of their peers. Other research (Levine and Linn, 1977), especially in the area of values, suggests that having a teacher or other authority figure present to defend a formal model in contrast to the student's Representational model aids in the transition. The findings are indecisive and probably a mixed-strategy that includes both instructor presentations and peer discussions is the approach most likely to encourage growth.

Once it is clear that students are capable of Formal Operations, they should be given Formal problems to solve and to generalize from.

SUMMARY: A LEARNING READINESS AXIS

> We shall not cease from exploration
> And the end of all our exploring
> Will be to arrive where we started
> And know the place for the first time.
> - T.S. Eliot, Four Quartets

The basic elements of children's environments do not change very much from year to year, but there is a rather dramatic change in children's abilities to conceptualize that environment effectively. Indeed, there is strong evidence that children go through at least three major reorganizations in the way they conceptualize reality, dividing childhood into four periods: Sensorimotor, Preoperational, Representational, and Formal Operational. In each of these periods children approach problems in a different manner, using different assumptions. Children make the transition at different times, but as far as is known, all children go through the stages in the same order and in each case display a type of reasoning appropriate to the period they are in.

Curriculum designers concerned with elementary, high school, college, and adult education need to be concerned with only two of these periods, the Representational and the Formal Operational, and the transition between them. By keeping in mind the characteristics typical of each of these periods, as well as during the transition, designers can predict which instructional sequences are most likely to be effective.

To aid readers in conceptualizing the impact of development on learning we have prepared the following Learning Readiness Axis, which can be placed on the vertical side of an instructional sequence to indicate the approximate sequence of development.

DEVELOPMENTAL PERIOD	IMPORTANT CHARACTERISTICS
FORMAL OPERATIONS PERIOD	Abstract concepts of functions and the ability to hypothesize possible variables or outcomes.
TRANSITION	
REPRESENTATIONAL PERIOD	Elaborate Representational Models and Hierarchies Reversibility [A]↔[B]
TRANSITION	
PREOPERATIONAL PERIOD	Mapping [A]→[B]

Figure 15. A LEARNING READINESS AXIS

II. LEARNING AND DEVELOPMENT

> Instruction is, after all, an effort to assist or to shape growth....And a theory of instruction is in effect a theory of how growth and development are assisted by diverse means.
>
> Jerome S. Bruner (1966)

KNOWLEDGE AND HIERARCHIES

Developmentalists tend to think in terms of the types of problems a student can handle at a particular age, the problem-solving strategies the student would use and the working memory capacity and retrieval strategies the student might bring to bear on problems. Few developmentalists have been concerned with instruction itself. Piaget has rarely spoken of the practical problems of designing instruction, preferring to concentrate on determining the abstract features of the child's capacity and otherwise allowing the child to develop at his or her own rate.

Learning theorists, on the other hand, have been very involved in instruction. Some have designed instructional techniques like programmed instruction and contingency management (Skinner, 1968; Homme, 1968; Evans, et al., 1960: Gilbert, 1978). Others have been active in curriculum design and development (Gagné, 1970; Mager, 1962). In the process of applying their theory to the actual subject matter to be taught, learning theorists have developed a number of important instructional concepts, including, for example: instructional objectives, successive approximation, mastery learning, and learning hierarchies. Anyone faced with the practical problems of designing, developing, and implementing an instructional program should necessarily turn to the literature of the learning theorists, since it is a large, detailed literature concerned with applying laboratory results to classroom settings.

There are, however, some serious problems with the behavioral approach. As Fischer has nicely summed it up: "Behaviorists have been investigating learning for many decades, but they have had little success in explaining either phases in the learning of a skill or the occurrence of transfer" (Fischer, in press). Our survey of the current cognitive developmental literature, especially the neo-Piagetian work in the information processing tradition, leads us to believe that a synthesis of the two approaches is possible and, indeed, that it is well under way. Learning theorists are beginning to incorporate developmental and cognitive components into their theories (Mahoney, 1974) and developmentalists are beginning to become very interested in the practical problems of instruction (Case, 1974).

In this section we intend to review briefly some of the important distinctions learning theorists have made and then to offer an initial, tentative synthesis that can guide curriculum designers.

INSTRUCTIONAL OBJECTIVES

As we have noted, many learning theorists have been concerned with the practical problems of instruction. Thus, they have necessarily been concerned not only with instruction but also with the selection and conceptualization of the subject matter to be taught.

One of the important innovations learning theorists have introduced is the idea that instruction ought to be designed to accomplish precisely specified objectives.

Mager, in Preparing Instructional Objectives (1962) defined the function of a good instructional objective as follows:

(1) It should describe what the learner will do to demonstrate that he or she has acquired the desired behavior.

(2) It should describe the conditions under which the learner must demonstrate the behavior, and

(3) It should state the standards of behavior expected of the learner. In other words, it should tell us how to discriminate between an acceptable and an unacceptable performance of the desired behavior.

Mager went on to say that the writer of instructional objectives should employ specific action verbs that preclude misinterpretation and provide sufficient detail to assure that other qualified persons in the field can recognize the behavior.

Instructional objectives commonly combine instructional concepts with actual skills. The same objective will specify the subject matter to be mastered and the process by which the student is to demonstrate mastery.

The specification of instructional objectives led naturally to concerns with sequencing. For a while, learning theorists thought of sequencing primarily in terms of strings of instructional objectives (e.g., linear programmed instruction). Since the late

1960's, however, the emphasis has shifted to the development of learning hierarchies that specify how a large number of objectives can be brought together; the leading proponent in this movement has been Gagné, and we will review his approach in more detail later in this chapter.

In general, two types of hierarchies have been investigated. One type of hierarchy places the emphasis on the subject matter to be learned and attempts to specify what facts and concepts should be learned first and how those initial facts and concepts can be grouped together to generate higher order concepts. The apex of a subject matter hierarchy specifies the broadest generalizations or principles to be mastered in a particular subject area (Bloom, et al., 1956).

The second type of hierarchy emphasizes the physical, cognitive, or affective skills the student is to learn. This type of hierarchy begins by specifying entry level skills and then indicates how such basic skills can be combined to produce more complex skills (Gagné, 1970).

Despite considerable work in developing algorithms to guide curriculum designers in the development of subject matter and skill hierarchies, no widely acceptable technology is available. Both types of hierarchies are developed by means of creative intuition combined with a feeling of logical consistency. In other words, people get together and talk about what the goals of a course are and then they work backwards, trying to determine what the students will have to know first if they are to ultimately master the selected goals. The most valuable techniques, in this regard, involve developmental testing (i.e., formative evaluation) and the revision of the hierarchy until it works consistently (Bloom, 1971).

It seems likely that one of the first fruits of a serious combined learning-developmental approach to curriculum design will be more rational and precise techniques for the specification of learning hierarchies.

GAGNÉ'S LEARNING HIERARCHY

Gagné published the second edition of The Conditions of Learning in 1970. In this important synthesizing work, he not only defined hierarchical relationships between a number of different kinds of learning, but he also anticipated many of the developments of the seventies.

Although Gagné is essentially a behaviorist, his view is broader and more eclectic than most. We will take the time to consider Gagné in some detail because his position represents the best alternative to ours, which calls for the integration of learning theory and development.

Gagné defines learning and the learner as follows:

> Learning is a change in human disposition or capability, which can be retained and which is not simply ascribable to the process of growth. The kind of change called learning exhibits itself as a change in behavior, and the inference of learning is made by comparing what

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> behavior was possible before the individual was placed in a "learning situation" and what behavior can be exhibited after such treatment. The change may be, and often is, an increased capacity for some type of performance. It may also be altered disposition of the sort called "attitude," or "interest," or "value." The change must have more than momentary permanence; it must be capable of being retained over some period of time. Finally, it must be distinguished from the kind of change that is attributable to growth, such as change in height or the development of muscles through exercise.

He goes on to say:

> Events in his environment affect the learner's senses and start chains of nervous impulses that are organized by his central nervous system, specifically by his brain. This nervous activity occurs in certain sequences and patterns that alter the nature of the organizing process itself, and this effect is exhibited as learning (Gagné, 1970).

Notice that Gagné excludes "change that is attributable to growth" from his definition of learning. On the other hand, he grants much to the cognitive/developmental point of view when he speaks of learning as something that "occurs in certain sequences and patterns that alter the nature of the organizing process itself."

In this monograph we have argued that existing evidence suggests an orderly growth in cognitive ability. Following Piaget, we have suggested that a child matures through four general periods, each of which is characterized by particular executive strategies, memory capabilities, and, ultimately, by the models of reality that the child can use to assimilate and interpret the sensory data he or she perceives. We have further argued that the child stretches and exercises each general type of model before proceeding to the successive types of models. Indeed, it is the very process of stretching and exercising particular models that finally leads the child to reorganize his or her approach and to begin conceptualizing perceptions in terms of models more appropriate to the succeeding period.

Following a developmental point of view, we have argued that the ability of mind to conceptualize the world in terms of successively more sophisticated models is developed through exercise, just as the muscles develop through exercise and height accumulates with the intake of food and the passage of time. Thus, we draw a distinction between the opportunity to learn, which typically includes all of the mental exercise the child naturally participates in, and instruction, which is learning directed toward some instructional objective. Obviously they can occur simultaneously, but they need not. Gagné is not concerned with the opportunity to learn, which he would call "the kind of change that is attributable to growth," and thus defines "learning" more narrowly than we have throughout this monograph.

Gagné describes eight types of learning. He further postulates a hierarchy in which type 2 leads, through each successively higher type, to type 8. Gagné defines the types as follows:

> "*Type 1: Signal Learning*. The individual learns to make a general, diffuse response to a signal. This is the classical conditioned response to Pavlov (1927).
>
> "*Type 2: Stimulus-Response Learning*. The learner acquires a precise response to a discriminated stimulus. What is

learned is a connection (Thorndike, 1898) or a discrimnated operant (Skinner, 1938), sometimes called an instrumental response (Kimble, 1961).

"*Type 3: Chaining*. What is acquired is a chain of two or more stimulus-response connections. The conditions for such learning have been described by Skinner (1938) and others, notably Gilbert (1962).

"*Type 4: Verbal Association.* Verbal association is the learning of chains that are verbal. Basically, the conditions resemble those for other (motor) chains. However, the presence of language in the human being makes this a special type because internal links may be selected from the individual's previously learned repertoire of language (see Underwood, 1964).

"*Type 5: Discrimination Learning*. The individual learns to make n different identifying responses to as many different stimuli, which may resemble each other in physical appearance to a greater or lesser degree. Although the learning of each stimulus--response connection is a simple type 2 occurrence, the connections tend to interfere with each other's retention (Postman, 1961).

"*Type 6: Concept Learning*. The learner acquires a capacity for making a common response to a class of stimuli that may differ from each other widely in physical appearance. He is able to make a response that identifies

> an entire class of objects or events (see Kendler, 1964). Other concepts are acquired by definition, and consequently have the formal characteristics of rules.
>
> "*Type 7: Rule Learning*. In simplest terms, a rule is a chain of two or more concepts. It functions to control behavior in the manner suggested by a verbalized rule of the form, 'If A, then B,' where A and B are previously learned concepts. However, such a rule must be carefully distinguished from the mere repetition of a verbal statement, which, of course, may also be learned as type 4.
>
> "*Type 8: Problem Solving*. Problem solving is a kind of learning that requires the internal events usually called thinking. Two or more previously acquired rules are somehow combined to produce a new capability that can be shown to depend on a 'higher-order' rule" (Gagné, 1970).

Gagné later expands on his definition of concept learning as follows:

> In order to state that the child is using a concept, one must be able to demonstrate that the performance is impossible on the basis of simpler forms of learning. This can be done (for example)...by presenting the child with novel stimulus objects in novel positions. If he responds correctly, it may be justifiably said that he "knows what the odd one is," or that he knows the concept odd.

> The possession of the capability generated in the learner when a concept is acquired is distinguished from all other forms of learning so far described by the characteristic of generalizability.
>
> The effect of concept learning is to free the individual from control by specific stimuli....The "test" for the presence of concepts is itself a matter of demonstrating that generalizing can occur....There must be a demonstration that the learner can generalize the concept to a variety of specific instances of the class that have not been used in learning. Otherwise, it is not a concept, but merely a collection of specific chains.

Gagné goes on to differentiate between two types of concepts: (1) concrete concepts, which he also terms "concepts by observation" and which involve sets of things that can be denoted by pointing to them, and (2) defined concepts, which involve relations between two or more concrete or other defined concepts. He gives an example of a defined concept as "a diagonal line is a line connecting opposite corners of a quadrilateral," and notes that the comprehension of "diagonal line" assumes that the student already understands the simpler concepts of "line" and "opposite corners in a quadrilateral." In this case, "line" can be an example of a concrete concept while "opposite corners in a quadrilateral" is a defined concept comprised of "opposite corners" and "quadrilateral."

Gagné also makes an interesting distinction between thing concepts and relational concepts. In terms of rules, thing concepts turn out to be noun phrases while relational concepts are verbs. Thus, in the rule: "A pint, doubled, is a quart," "pints" and "quart" are thing concepts while "doubled" is a relational concept.

Gagné makes it clear that each of us, throughout life, is always using all of the various types of learning, depending upon the situation we find ourselves in. Piaget, as we have already noted, also claims that we use the models appropriate to different periods throughout life.

Gagné goes on to argue that all higher learning is based on hierarchies of concepts and rules. Gagné's hierarchies are all hierarchies of "intellectual skills or processes," as opposed to subject matter concepts. He notes that an intellectual skill is "something that the learner is able to do with reference to his environment." Gagné argues that the lower level concepts and rules must be mastered before the higher level concepts or rules can be taught. He says:

> Learning hierarchies are the best way to describe the "structure" of any topic, course, or discipline. They describe the intellectual skills the individual needs to possess in order to perform intellectual operations within that subject--to learn about it is to think about it, to solve problems in it. Verbal information about a subject can be looked up....Intellectual skills, however, cannot be looked up; they must be learned (Gagné, 1970).

Children in the Sensorimotor Period (from birth to eighteen months) clearly demonstrate signal learning, stimulus-response learning, and chaining. Verbal association, when it begins to occur, marks the child's transition from the Sensorimotor Period to the Preoperational Period. Types 1 through at least 6 all occur commonly during the Preoperational Period.

Gagné's discrimination between defined and concrete concepts, however useful, should not be confused with a Piagetian difference between Representational and Formal concepts. Defined concepts (e.g., diagonal line) may be quite Concrete (i.e., one can easily point to a diagonal line in a geometric figure). Likewise, both Gagné's Rule Learning and Problem Solving states may be exemplified by the Representational student.

Beyond the beginning of the Representational Period all students are capable of displaying all eight types of learning in one situation or another. Thus, Gagné's hierarchy does not permit us to capture the important differences between Representational and Formal students. Some of the more complex hierarchies that Gagné has constructed suggest a distinction between lower level concepts and rules that a Representational student can deal with and higher level concepts and rules that only a student capable of Formal Operations could handle. Here we especially need to be able to distinguish explicitly between rules and defined concepts that involve only Representational concepts (i.e., sets of things that can be observed) and rules and concepts that clearly involve Formal concepts.

Gagné's learning types are extremely useful whenever we want to consider instructing students to accomplish a particular task. It is inadequate, however, when we are concerned with the development of a curriculum that will extend into the Formal Period.*

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*Gagné has recently updated his position to incorporate a more cognitive emphasis on memory, although it remains essentially unchanged (Gagné and White, 1978).

THE RELATIONSHIP BETWEEN LEARNING AND DEVELOPMENT

> According to Piagetian theory, the fit between the child's existing knowledge and the new information presented is a critical determinant of when, how much, and what kind of learning will occur.
>
> R. S. Siegler (1976)

The relationship between development and learning is frought with problems and is still the subject of extensive research. Although some general answers have begun to emerge, they will undoubtedly be considerably qualified or even revised in the years ahead. Here we will present a general picture that can guide individuals who are actively involved in teaching and curriculum design. Readers must bear in mind, however, that our conclusions are of a tentative nature.

To a learning theorist, learning is commonly defined as a change in behavior that can be measured in terms of a change in the rate of performance of specific overt actions. Such learning can be random and unplanned. For example, a child who learns that by turning a particular knob he or she can make the TV picture appear and disappear has learned in an unplanned manner. Learning can also result from the presentation of specific stimuli, the modeling of specific responses, and the planned reinforcement of desired responses. When instructional technologists speak of learning, they commonly refer to an environment with specific instructional objectives, a systematic program of instruction and planned consequences contingent upon acceptable responses.

To a developmental theorist, learning is commonly defined as systematic behavior change that occurs as a result of the child's natural interactions with his or her environment. In other words, when developmentalists talk about learning they commonly assume that the child learns in the natural course of everyday experience.

Note that there is nothing incompatible between the assumptions of the developmentalist and the learning theorist, but there is a different emphasis. Where the learning theorist commonly emphasizes planned instructional situations and specific behavioral changes, the developmentalist emphasizes less structured and more holistic experiences that foster general behavioral changes.

Learning theorists claim that they can teach a child almost any particular skill at any age, if they use a proper instructional sequence and sufficient reinforcers (Gagne, 1977).

Developmentalists, relying heavily on the research of Piaget and his followers (Piaget, 1969 through 1976; Siegler, 1976), emphasize that children of a particular age learn some things easily and other things with great difficulty or not at all. Moreover, developmentalists claim that there is a broad consistency among the general types of tasks a child can perform at a particular age.

Originally Piaget maintained that maturation was simply a matter of the child's interaction with the natural environment. In this view, the developmental process was largely fixed and the educator was advised to concentrate on teaching the skills appropriate to the period the child was currently in. American developmentalists, especially Bruner and his associates, have demonstrated that planned instruction can, at certain times and under certain conditions, change the child's problem solving strategies (Bruner, 1960). And, indeed, Piaget himself has recently conceded this (Inhelder, et al., 1974), although he continues to emphasize general experience over planned instruction.

In considering various studies of learning and development we conclude that the single variable that seems the most open to differing interpretations is the generalization (or transfer) of a problem solving strategy from one task to another. The learning theorist defines generalizations narrowly and uses it to refer to learning transfer between relatively similar tasks. By contrast, developmentalists define generalization quite broadly and tend to focus on the transfer of learning from a particular task to a very broad category of tasks involving similar principles but quite different observable stimulus qualities. This contrast is illustrated by the literature on generalization published by learning theorists who primarily refer to things like pigeons and rats learning to make the same response to pink and red lights (Ferster and Skinner, 1957) and by the opinion of developmentalists who assert that learning theorists have never demonstrated generalization (Fischer, in press). It is clear to us that when each group uses a term like "generalization" to mean such different things, communication is constrained.*

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*A nice example of the way the use of the concept generalization can confuse the debate between learning theorists and developmentalists

To illustrate the developmental notion of generalization, consider two problems typically used by Piaget to discriminate the Preoperational child from the Representational child. At three years of age the Preoperational child does not have the concept of the conservation of substance. Thus, if shown two equal clay balls (Figure 16) and asked: "Are they the same, or does one have more clay in it than the other?" children say, "They are the same." Then, if one of the balls is rolled into a sausage shape as children watch and they are then asked the same question, they typically respond that one object now has more clay than the other. Usually children will maintain that the sausage has more clay.

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appeared in the American Educational Research Journal in the Fall of 1978 (Martinko & Clifford, 1978). The authors summarize their research as follows:

> There is evidence to indicate that the experimental induction of conservation behavior is dependent upon an empirical specification of operational reversibility. On the other hand, it has been demonstrated that conservation can be induced with S-R principles which call attention to the relevant quantitative dimensions and away from irrelevant perceptual dimensions. In this study, training methods representative of those two positions are used to induce conservation of area. Data show that both methods are highly effective as compared to a control, and support the conclusion that the empirical specification of reversibility is not a requirement for conservation induction.

When one studies the actual experiments that Martinko and Clifford base their conclusions upon, one is struck with the fact that the claim depends upon the degree of generalization that the subjects can be shown to display. In fact, the stimuli compared are geometric figures. To a behaviorist accustomed to animal studies or to developing programmed instruction in the recognition of geometric shapes, the stimuli are quite different and seem to support a claim that the subjects display considerable generalization. To a developmentalist accustomed to thinking of problems as diverse as balance scales, various sized glasses of fluid, and verbal answers to moral dilemmas as all variations on a common underlying intellectual operation, the test items used by Martinko and Clifford are much too similar too prove that generalization has occurred.

A similar problem involves two cords placed beside each other. At three years, children will initially say that the two cords are of similar length and then, having watched while the experimenter twists one into an "S," assert that the straighter string is the longer of the two.

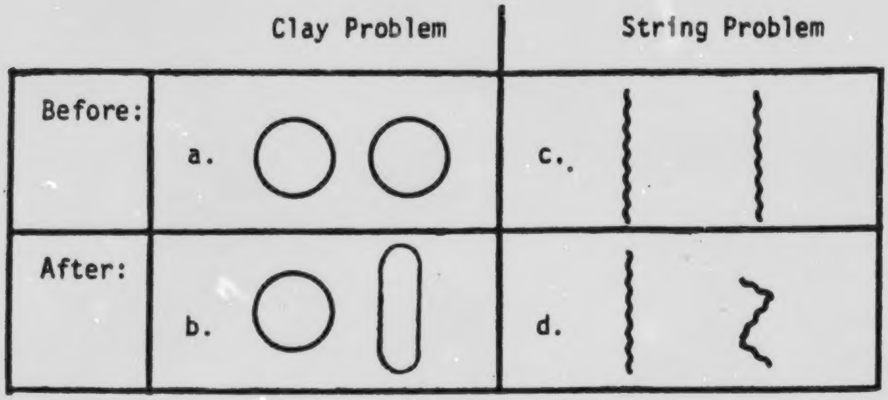

Figure 16. THE CLAY AND THE STRING TASKS

In Piagetian terms, the Preoperational child's thinking lacks reversibility; the child is not yet able to compare the before and after conditions. Instead the question is answered on the basis of what the child sees in the instant in which he or she is questioned. Moreover, the child centers on one specific feature, usually the longest straight segment, to determine which "has the most" or is "longest."* Developmentalists consider the ability to recognize the conservation of matter as it changes shape as the critical skill involved in both these tasks.

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*Fischer's notation: [A] → [B], where [A] is the before condition and [B] is the after condition.

By about nine years of age, the child is in the Representational Period and can easily answer both questions correctly. He or she has now acquired the concepts of conservation of substance and length and is thus certain that if the two clay balls were the same before a transformation they are also the same afterwards. Piaget says that the Representational child has acquired the ability to mentally reverse the demonstration and to consider the before and after conidtions essentially simultaneously.* He would also say the child can generalize the concept of the conservation from one task to others.

Note that the three year old will normally get both the ball and the string problems wrong while the nine year old will normally get them both right. This is a good example of the type of cross-task consistency that led Piaget to postulate periods. If one assumed, as learning theorists commonly have, that the child's skills were just the result of his or her prior experience, then we should not expect these cross-task consistencies. Instead, we should expect each child's performance to vary according to his or her specific prior experience with different tasks. We would not expect this if we used the developmentalist's concept of generalization. The behaviorist, however, construes generalization more narrowly and would tend to deny that the child would experience learning transfer between the string problem and the clay problem.

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* In Fischer's notation: [A] → [B].

Let us now consider some variations on this experiment generalized from the work of a number of different experimenters. If we set out to teach the three year olds that the clay in the ball and the sausage are equal, we could do it. It would take a lot of work and time, but finally the children would learn to say that each contains the same amount of clay. Typically, however, they would not remember it for very long, and, more importantly, if we move from the clay to the string problem children will maintain that the straighter string (d) is the longer string. Thus, we can teach Preoperational children of three to solve the clay problem correctly, but we apparently can not teach them to generalize what they have learned to other similar situations. In other words, learning is task-specific. Moreover, retention is poor, leading the developmentalist to suggest that the child has not really grasped the underlying concept.

Consider a second subject -- a six year old child who is in transition from the Preoperational to the Representational Period. Initial tasks show that the child fails to get the right answer to either the clay or the string problem. We now instruct the child in the correct solution to the clay problem. The child quickly learns to give the correct response. Moreover, when presented with the string problem, the child gets it right. And the solution is remembered.

The strong developmental claim is that when children are ready to learn a particular strategy, learning occurs quickly and generalizes extensively. On the other hand, if children are not yet ready to use a particular strategy, instruction takes longer, and learning tends to be task-specific with little or no generalization occurring.

Case (1978b) has noted that there are essentially four learning strategies relative to a particular task.

I. *Exposure to similar task situation.* In this strategy the child is simply allowed to explore a number of different situations. Accomplishing the task is the result of accumulated experience, or maturation. This is the strategy initially and primarily recommended by Piaget. It assumes that when the child's general problem solving cognitive structures reach sufficient sophistication, the child will rapidly learn to perform the task (cf. Gibson, 1969; Piaget, 1971).

II. *Exposure to similar task situations with feedback.* In this case, the child is allowed to explore, but feedback is provided when the child approximates or actually performs the task. In behavioral terms, this procedure induces focus and includes reinforcement of approximations to the desired task performance (cf. Halford, 1970; Klahr & Wallace, 1976).

III. *The relevant unattended feature(s) of the task are pointed out to the student.* This strategy aims at getting the child to focus on stimuli that he or she is currently ignoring. This strategy assumes that the child will be able to perform the task when he or she attends to all the relevant stimuli (cf. Gelman, 1967).

IV. *The correct solution is modeled for the student.* In this case the instructor demonstrates to the child how to go about performing the task. The student is encouraged to do the task the same way the instructor did. Unattended features are pointed out and feedback is provided to help the student match the behavior modeled by the instructor (cf. Gagné, 1968; Bandura, 1969).

These four approaches are summarized in Figure 17. In addition, Figure 17 shows how each instructional strategy breaks down into behavioral units (e.g., cue attending) as well as what degree of generalization we can expect from each strategy.

LEARNING STRATEGY	Correct Responses Reinforced (Feedback)	Stimulus Control Sought (Cue Attending)	Actual Performance (Modeling)	Time Required for Learning Task	Generalization from One Task to Others	General Approach
(I) Exposure to task situations	---	---	---	Longest	Best Transfer	Involves opportunity to learn
(II) Exposure plus feedback	Yes	---	---	Long	Some Transfer	
(III) Unattended features	Yes	Yes	---	Short	Little Transfer	Involves instruction
(IV) Model for correct solution	Yes	Yes	Yes	Shortest	Least Transfer	

Figure 17. EFFECTS OF FOUR LEARNING STRATEGIES

This chart assumes that we are trying to teach a child to perform a task that the child is not typically performing in his or her current developmental period (e.g., teaching a three year old to recognize that the amount of clay is the same in both the ball and the sausage). Modified after Case (1968b).

The classic Piagetian strategy is exposure (Strategy I). The child simply lives in an environment containing problems similar to those tested by the various Piagetian tasks. The child is allowed to interact with the environment until the solution occurs naturally. Piaget has always emphasized that the transition between periods occurs rapidly--almost instantaneously--so when we indicate that the time required for learning the task is the longest, we are assuming that the child is *not* ready to learn the task and that natural maturation will take a few years as the child passes from the Preoperational Period to the Representational Period. Once the transition occurs, however, the child will solve the particular task and will easily and rapidly solve numerous related tasks.

In the case of exposure plus feedback (Strategy II), the child is not rushed, but correct approximations and responses are reinforced. This strategy seems to accelerate the acquisition of the task performance. On the other hand, the child may not generalize the performance to similar tasks. In effect, we use the feedback contingency to focus the child's attention on a particular task and thus speed the child to its solution at the expense of generalizability.

Both I and II involve what developmentalists refer to as opportunity to learn, as distinguished from Strategies III and IV which explicitly involve instruction. The second strategy is mixed since the child is not instructed in the task, but is given feedback when the desired performance occurs. If we discriminate between motivation (which involves consequences) and instruction, which involves stimulus control (Homme, 1968) we can say that II involves opportunity plus specific operant motivation but does not include instruction.

Learning Strategy III, in which the unattended features of the task are highlighted, definitely involves instruction. Using a combination of cueing and feedback, an instructor can lead the student to solve the task in a relatively short time. However, little transfer or generalization between the specific task and similar tasks can be expected. Moreover, retention is usually poor unless a specific schedule is established that calls for and reinforces the specific task performance on a relatively frequent basis.

Learning Strategy IV is the classic strategy of behavioral or social learning theorists. The task is demonstrated to the child. Salient features are highlighted and approximations of the correct response are reinforced. This procedure is repeated until the child masters the task. This strategy, using all the tools in the instructional technologist's repertoire, can help the child attain correct task performance in the minimum time. However, it also results in the least generalization. And retention, as with Strategy III, is poor unless a schedule of repeated exercises is established.

Both Bruner (1960) and Skinner (1968) assert, for slightly different reasons, that we can use Strategy IV to teach a child almost anything at any age. However, if we are trying to teach a five year old a task that is not commonly learned until the age of seven, we will need to spend a relatively large amount of instructional effort on the project and the child will retain the performance only if we establish a systematic program of reinforcement. Moreover, generalization will be poor.

Perhaps one of the best things to come out of considering the relationship between learning and development is the precision it allows us in framing this type of question and examining instruction in the light of the resulting discriminations.

DEVELOPMENTAL LEVEL OF STUDENTS	NATURE OF INFORMATION TO BE LEARNED	
	REPRESENTATIONAL INFORMATION	FORMAL INFORMATION
REPRESENTATIONAL OPERATORS	NO PROBLEMS Use normal instructional techniques. Theory should be confined to representational models or images.	PROBLEMS! Specific tasks should be simplified to the point where they can be solved by representational operators. And since one should not expect good retention, one should be prepared to aid the student during actual performance.
FORMAL OPERATORS	NO PROBLEMS Use normal instructional techniques. Theory can be representational or abstract.	NO PROBLEMS Use normal instructional techniques. Theory should be abstract or formal.

Table 2. ANALYSIS OF THE INSTRUCTIONAL IMPLICATIONS OF THE INTERACTION BETWEEN THE REPRESENTATIONAL AND FORMAL ASPECTS OF INFORMATION TO BE LEARNED AND THE DEVELOPMENTAL LEVEL OF THE STUDENT. (Harmon S. King, 1979).

Obviously, effective instructional techniques and materials exist to teach Concrete tasks to students who function at the Representational level (Evans, et al., 1960; Gilbert, 1978b). Likewise, we can effectively teach Formal tasks to students who are capable of Formal Operational thought (Case, 1968a, c; Harmon, 1970). But what of the other possibilities? Can we effectively teach Representational students to either (1) effectively perform Formal Operational tasks, or (2) to become capable of Formal Operational thought? The research on teaching Formal Operational thought is extremely complex and no simple conclusion can be reached (Strauss & Langer, 1970; Strauss, 1972;, Rohwer, 1973, Inhelder, Sinclair & Bouet, 1974; Siegler, 1976; Case, 1977; Levine & Linn, 1977). Insofar as we can teach Formal Operational thought, suffice it to say that it takes a lot of time and effort and is only partially successful.

Discussing the difference between encouraging a shift in level and encouraging skill development within an operational level highlights another difference between learning theorists and developmentalists. To a Piagetian, movement from one level to the next higher level involves overcoming inconsistencies and contradictions that are generated when the student seeks to apply his or her current repertoire of problem solving strategies to tasks for which they are insufficient. Thus, to encourage a level change, developmentalists design situations that confuse the student. For a Piagetian, this confusion is a necessary part of a process by which a student reorganizes his or her basic cognitive structures in order to be better able to deal with the demands of the tasks he or she is confronting.

This confusion is inappropriate and unnecessary, however, when the student is solving problems that are currently amenable to his or her current repertoire of strategies and skills. Learning theorists have normally emphasized instructional strategies that minimize student errors. Instead of confusing the student, they have emphasized clear objectives, successive approximation, appropriate operant spans, and frequent feedback. They have sought, in other words, to teach students with a minimum of inconsistency and without confusing contradictions.

It may be that as learning theorists consider the problems of inducing shifts in operational levels they will develop strategies that rely more on contradiction and less on successive approximation; but for the moment it is probably safe to say that learning theorists are more comfortable focusing on teaching tasks that lie within an operational level, while developmentalists, when they are interested in instruction at all, have been more concerned with the problems of inducing changes from one operational level to the next.

At any particular age there is much we can and should teach children. We suggest environmental educators concentrate instructional strategies on critical learning objectives while relying on Strategies I and II to provide for overall growth. We can then use our instructional strategies (III and IV) for the more difficult or unusual tasks children need to learn in the period they are currently in. Thus, we can obtain the maximum generalization and retention for the minimal instuctional effort. In summary, we can use Strategies III and IV to teach important tasks appropriate to the period the child is currently in, while allowing Strategies I and II to simultaneously move children from their current period to the succeeding period.

III. THE ENVIRONMENTAL KNOWLEDGE BASE

An environmental knowledge base can be defined in a number of different ways. It can, for example, be defined in terms of environmental concepts that a student should comprehend when he or she completes each course (See Harmon & Sutton, 1974; Ekistics, 1973; and Dickey & Roth, 1972). Such a conceptual knowledge base is useful in providing an overview of a curriculum development effort since it provides, in effect, a comprehensive definition of all of the subject matter to be included in the curriculum. It is especially useful in environmental education, since the field is naturally interdisciplinary and thus is constantly concerned with questions about what subject matter should or should not be properly included in an environmental course.

In the analysis of environmental studies concepts conducted by Sutton and Harmon (1973), twelve general topics were used to define the horizontal axis of a matrix (See Table 3).

Specific concepts within each of these larger domains were identified and ranked from the more elementary and particular to the more complex and integrative. Working independently, Young (1974) developed a very similar general analysis of the subject matter that should be included in an environmental course.

A subject matter hierarchy is limited, however, in that it does not specify the behaviors that students will perform to demonstrate mastery of the subject matter. Obviously we do not simply want students

MAJOR CATEGORIES	SUB CATEGORIES
1. ENERGY	1.1. Energy in the Universe 1.2. Energy in Living Systems 1.3. Human Use of Energy
2. PATTERNS IN SPACE	2.1. Orderliness in the Universe 2.2. Population 2.3. Community Structure
3. PATTERNS IN TIME	3.1. Cycles 3.2. Evolution 3.3. Succession
4. HUMANKIND	4.1. Values 4.2. Institutions 4.3. Impact

TABLE 3. ONE POSSIBLE CLASSIFICATION OF THE CONCEPTUAL CONTENT OF ENVIRONMENTAL STUDIES

to memorize successively more complex verbal statements about environmental matters. The major alternative to subject matter hierarchies is a learning hierarchy that specifies successive levels of intellectual skills that the student should demonstrate. Indeed, Gagné and others developed a very impressive hierarchy for the basic intellectual skills of science (Gagné, 1968).

This hierarchy is useful in designing curriculum materials for the first three or four grades. It also illustrates the limit to this approach, namely that by trying to be exhaustive one runs into an incomprehensibly large number of possible skills that could reasonably be taught in an environmental studies course.

The Far West Laboratory for Educational Research and Development (FWL) has considered this problem in some detail and developed a synthetic approach that seeks to combine the best features of each of these two common types of hierarchies.

Initially FWL delineated two sets of content areas that need to be considered in environmental education: Natural Systems and Human Systems. Each of these areas was subdivied into Operational considerations and Conceptual considerations. Then, using these two lists of considerations as the axis of a matrix space of all possible environmental studies interactions, specific clusters of interactions were isolated as appropriate topics for the development of modules (See Figure 18).

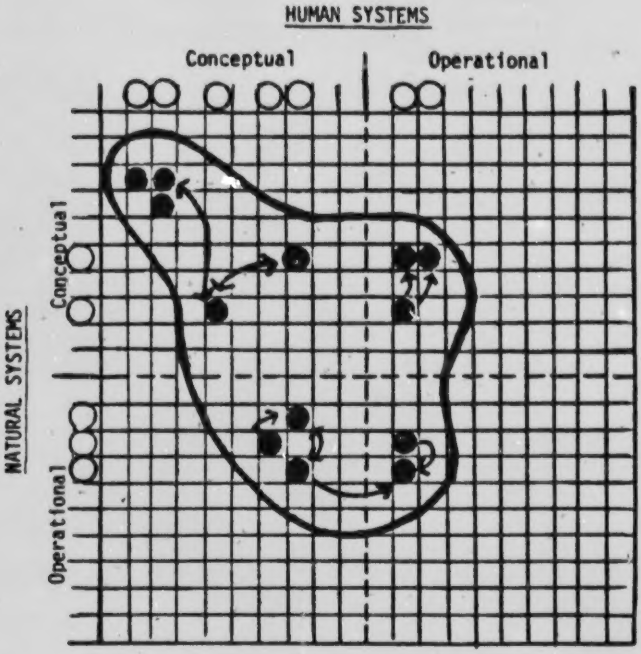

FIGURE 18. A MODULE DEFINED AS A CLUSTER OF INTERACTIONS BETWEEN THE POSSIBLE CONTENT OF NATURAL AND HUMAN SYSTEMS

The "root" natural and human systems concepts are indicated by white dots. The interactions between root concepts are indicated by black dots. The interactions between interactions are indicated by arrows. Taken together, these define the overall content of a module.

The product of this effort is called a contextual map. Figure 19, for example, illustrates the contextual map for a module on the Optimal Use of Finite Land Resources.*

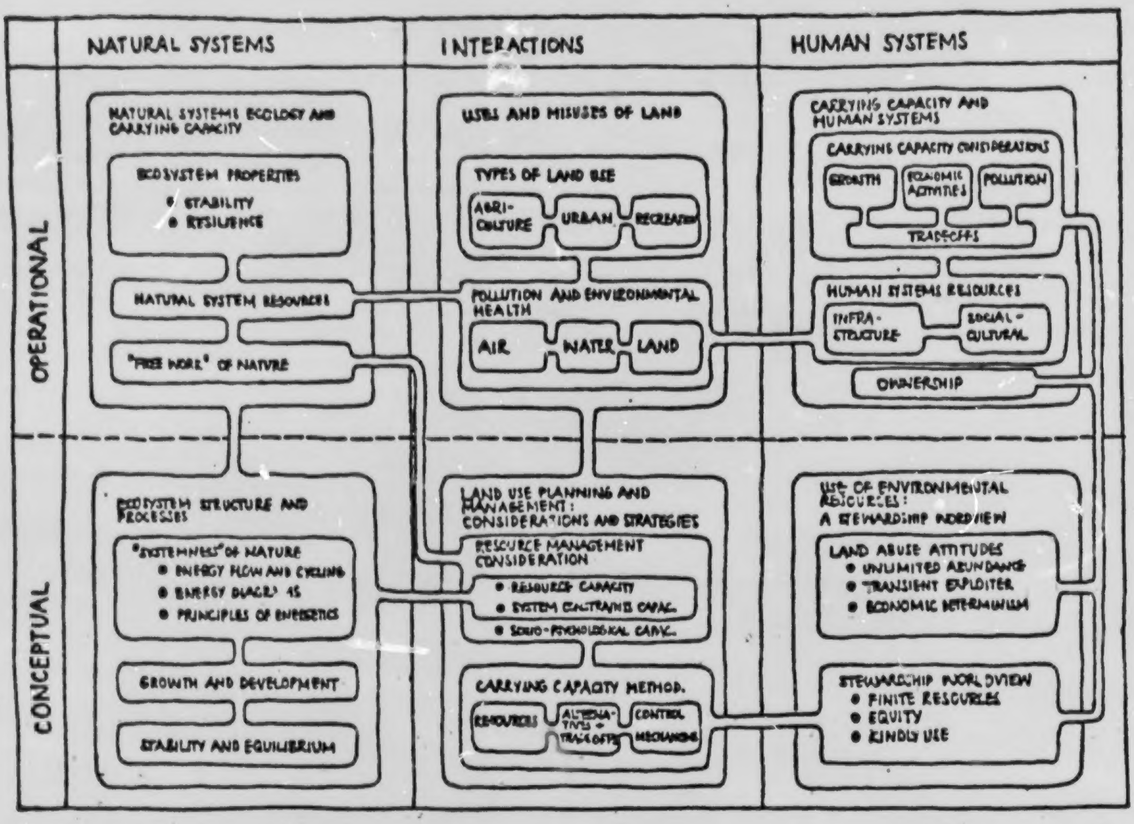
NATURAL SYSTEMS
INTERACTIONS
HUMAN SYSTEMS
OPERATIONAL
CONCEPTUAL
NATURAL SYSTEMS ECOLOGY AND CARRYING CAPACITY
ECOSYSTEM PROPERTIES
• STABILITY
• RESILIENCE
NATURAL SYSTEM RESOURCES
"FREE WORK" OF NATURE
ECOSYSTEM STRUCTURE AND PROCESSES
"SYSTEMNESS" OF NATURE
• ENERGY FLOW AND CYCLING
• ENERGY DIAGRAMS
• PRINCIPLES OF ENERGETICS
GROWTH AND DEVELOPMENT
STABILITY AND EQUILIBRIUM
USES AND MISUSES OF LAND
TYPES OF LAND USE
AGRI-CULTURE
URBAN
RECREATION
POLLUTION AND ENVIRONMENTAL HEALTH
AIR
WATER
LAND
LAND USE PLANNING AND MANAGEMENT: CONSIDERATIONS AND STRATEGIES
RESOURCE MANAGEMENT CONSIDERATION
• RESOURCE CAPACITY
• SYSTEM CONSTRAINTS CAPAC.
• SOCIO-PSYCHOLOGICAL CAPAC.
CARRYING CAPACITY METHOD.
RESOURCES
ALTERNA-TIVES + TRADEOFFS
CONTROL MECHANISMS
CARRYING CAPACITY AND HUMAN SYSTEMS
CARRYING CAPACITY CONSIDERATIONS
GROWTH
ECONOMIC ACTIVITIES
POLLUTION
TRADEOFFS
HUMAN SYSTEMS RESOURCES
INFRA-STRUCTURE
SOCIAL-CULTURAL
OWNERSHIP
USE OF ENVIRONMENTAL RESOURCES: A STEWARDSHIP WORLDVIEW
LAND ABUSE ATTITUDES
• UNLIMITED ABUNDANCE
• TRANSIENT EXPLOITER
• ECONOMIC DETERMINISM
STEWARDSHIP WORLDVIEW
• FINITE RESOURCES
• EQUITY
• KINDLY USE

FIGURE 19. THE CONTEXTUAL MAP FOR THE FWL MODULE ON "OPTIMAL USE OF FINITE LAND RESOURCES"

Note that a contextual map is arranged not only to show the interactions, but also to display the roots of those interactions in the Natural and Human Systems continuum. By this means the potentially infinite subject matter of environmental education is reduced to a manageable curriculum unit.

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*FWL has developed four teacher training modules: Optimal Use of Finite Land Resources, Energy Intensive Urban Growth and the Quality of Life, Energy-Conserving Resource Utilization, and Energy Resource Delivery Use.

The resulting contextual map provides content topics to be further developed. There are, in effect, two types of topics: thing topics and relational topics. Each of these topics becomes the potential apex of two separate hierarchies--a subject matter hierarchy and a process skills hierarchy (See Figure 20).

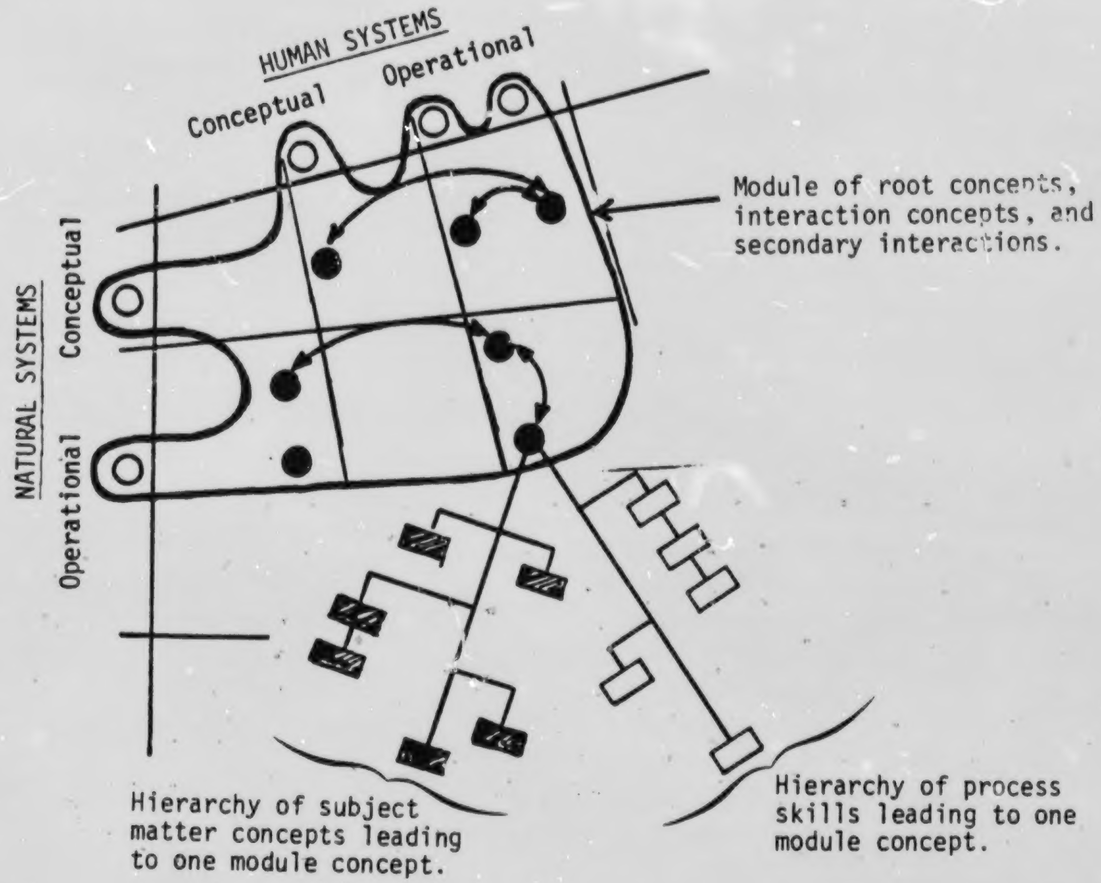

HUMAN SYSTEMS
Conceptual
Operational
NATURAL SYSTEMS
Conceptual
Operational
Module of root concepts, interaction concepts, and secondary interactions.
Hierarchy of subject matter concepts leading to one module concept.
Hierarchy of process skills leading to one module concept.

Figure 20. SUBJECT MATTER AND PROCESS HIERARCHIES CREATED FOR EACH MODULE WITH COMPONENT SKILLS

The white boxes indicate specific process skills while the black boxes are used to represent specific subject matter concepts.

Both subject matter and skills hierarchies can be created for root concepts (white dots), interaction concepts (black dots) and secondary interactions (arrows). Each of these relatively small hierarchies is developed during the design phase of module development. The subject matter hierarchies are developed with reference to existing hierarchies of environmental concepts (Sutton & Harmon, 1973), and the process skills hierarchies are developed following the traditional approach of Gagné, et al. (Gagné, 1968). Obviously, there is a close relationship between the two hierarchies, since skills are necessarily practiced in the context of a particular subject matter and vice versa. The content of both hierarchies is included in the FWL modules in the form of instructional objectives and sub-objectives.

We have argued in this monograph that the development of the process skills hierarchies should incorporate more considerations of the students' readiness to assimilate specific skills and concepts effectively and to generalize about them. At first reading, this approach may seem unduly complex. It has, however, two important advantages over simpler, more traditional approaches.

1. Hierarchies are developed only in the context of a specific module. This avoids the otherwise immense and potentially endless job of trying to specify all of the concepts and all of the intellectual skills that could be included in an environmental curriculum.

2. Traditional hierarchies commonly build to a single concept or intellectual skill. This is reasonable for certain subject matters, but it is counter-productive for environmental education since the final goal of environmental education should be to help students develop the capability for conceptualizing and thinking productively about a holistic problem-complex such as "land use" or "energy resource and delivery."

The development of small hierarchies, each related to specific components of an interacting system, helps to assure that curriculum designers, teachers, and students will conceptualize the educational effort as one leading to a holistic and systematic understanding (See Figure 21).

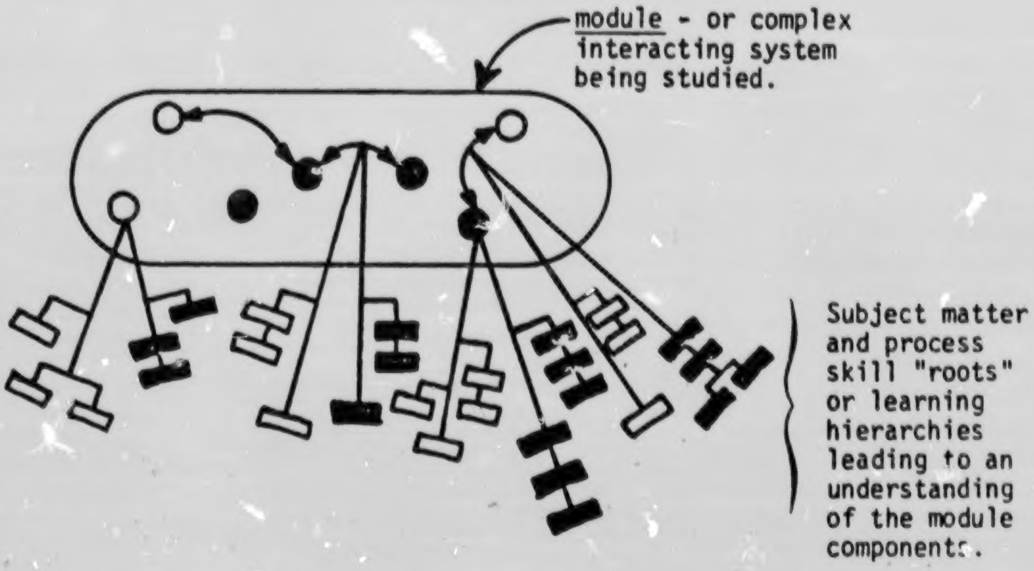

module - or complex interacting system being studied.
Subject matter and process skill "roots" or learning hierarchies leading to an understanding of the module components.

Figure 21. THE APEX OF MANY SUBJECT MATTER AND SKILL HIERARCHIES IS A SINGLE, HOLISTIC, INTERACTING SYSTEM

IV. A DEVELOPMENTAL/ENVIRONMENTAL LEARNING MATRIX

THE MATRIX

We have argued that environmental educators should be more aware of the learning readiness of their students. Our examination of the current state of research and model building in developmental psychology has suggested a developmental sequence that we believe can be useful in determining the order in which subjects can be taught. More important, it stresses the critical difference between students in the Representational Period and those in the Formal Operations Period. This critical distinction, we have noted, does not necessarily take place at a particular age and curriculum designers ought to strongly consider the possibility that any particular adult audience is as likely to be Representational as Formal, especially when faced with a subject area with which they are not familiar.

Environmental educators can conceptualize their task in terms of the developmental/environmental matrix space pictured in Figure 22, in which we depict the developmental periods on the vertical axis. In keeping with our discussion in Chapter I, we have shaded the transition between the Representational and Formal Periods to indicate that we believe this is the critical area with which environmental educators should be most concerned.

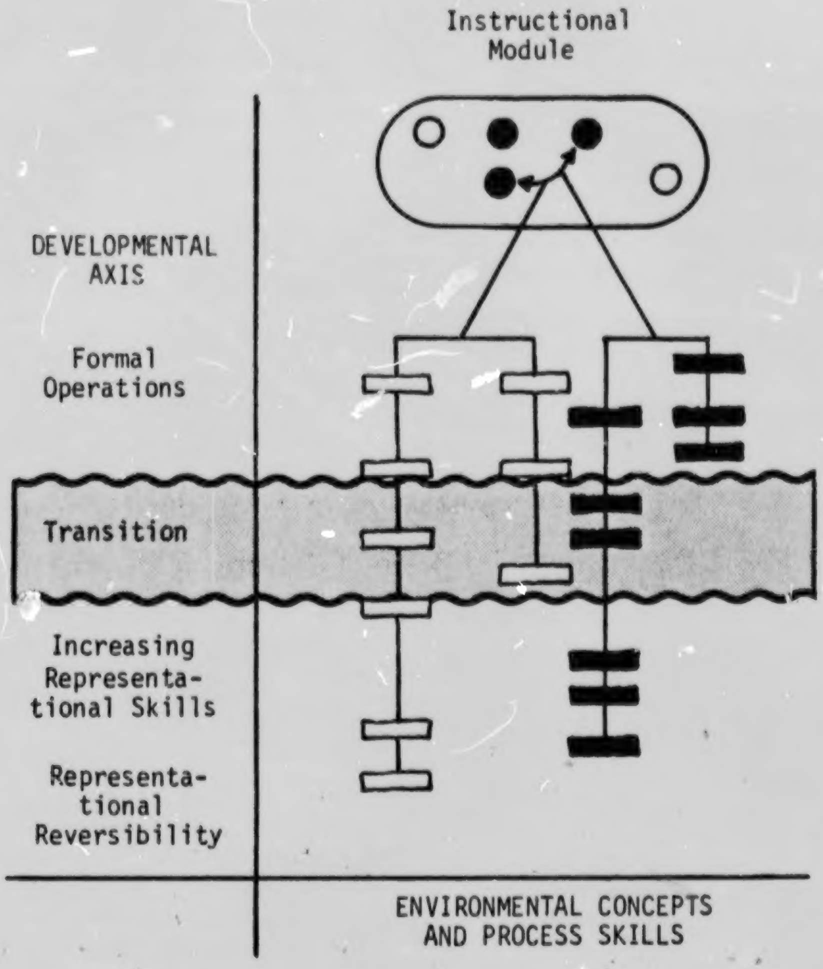

Instructional Module
DEVELOPMENTAL AXIS
Formal Operations
Transition
Increasing Representational Skills
Representational Reversibility
ENVIRONMENTAL CONCEPTS AND PROCESS SKILLS

Figure 22. DEVELOPMENTAL/ENVIRONMENTAL MATRIX SPACE WITH A TRADITIONAL FWL MODULE DEPICTED GRAPHICALLY

The horizontal axis in Figure 22 becomes the dimension of the environmental knowledge base. In keeping with FWL's approach, we have depicted a hypothetical, complete instructional module at the top and extended a process skill and a subject matter hierarchy downward into the matrix space.

What we now propose, as a result of our review of the developmental literature, is that the objectives of an instructional module, whenever possible, be designed to call for behavior that is typical of students in the late Representational stage or in transition between the Representational and Formal Periods. In addition, we propose that there be both a Representational and Formal interpretation of each objective.

In the hypothetical example in Figure 23, the instructional module is pictured as lying on the transition. This is meant to indicate that a student who is not capable of Formal Operations will nonetheless be able to comprehend the model on a Representational level.

In the example in Figure 23 we picture the interaction arrow (1) in the instructional model as the basis of two descending hierarchies: (a) a hierarchy of process skills and (b) a hierarchy of subject matter concepts. Both of these hierarchies should be constructed entirely in terms of abilities and concepts that a Representational student is capable of mastering. Thus, the instructional module itself should be entirely comprehensible, as a Representational model, to a student who is not capable of Formal Operations.

We further propose that hierarchies of (c) Formal Operational processes and (d) subject matter be included in the instructional module as enrichment. Thus, the model should be capable of being viewed entirely in Representational terms, in Formal terms, or as a mixture of both modes.

We do not believe that such a design will be easy to arrange, but we believe the extra effort will offer significant advantages.

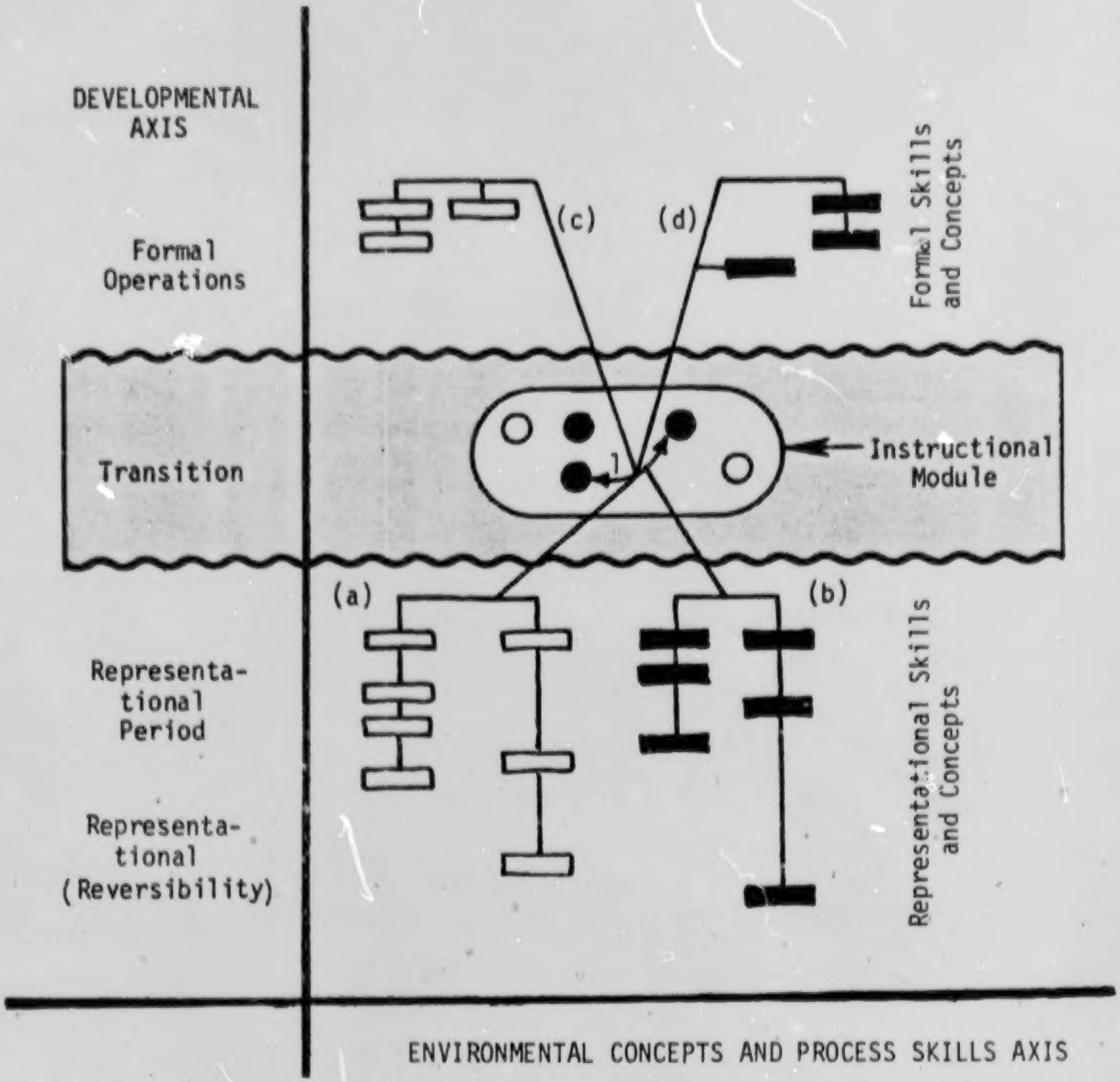

DEVELOPMENTAL AXIS
Formal Operations
Transition
Representational Period
Representational (Reversibility)
(a)
(b)
(c)
(d)
1
Instructional Module
Formal Skills and Concepts
Representational Skills and Concepts
ENVIRONMENTAL CONCEPTS AND PROCESS SKILLS AXIS

Figure 23. THE DEVELOPMENTAL/ENVIRONMENTAL MATRIX SPACE WITH AN INSTRUCTIONAL MODULE CENTERED ON THE TRANSITION BETWEEN THE REPRESENTATIONAL AND FORMAL PERIODS

- It will assure that students, as well as adults, who are not yet capable of Formal Operational thought relative to the subject being taught, will nonetheless be able to understand the essential contents of the module.

- Because it will be open to two interpretations, it will aid Representational students in the transition to Formal Operations.

- Because it will be open to a Formal interpretation, it will not limit students capable of Formal Operations.

- Because it includes both Representational and Formal interpretations it will also provide a means for assessing the level at which participating students are functioning.

The alternative, pictured in Figure 22, requires that either (1) students be screened to assure that they are all capable of Formal Operations (a dubious possibility), or (2) that the module itself be capable of teaching Representational students to perform specific Formal Operations (a very dubious possibility), or (3) that Representational students be left behind and fail to really understand what the module is all about (which is what probably happens now).

We have already noted that any specific Formal concepts or intellectual processes can probably be taught to Representational students but that this requires a considerable instructional effort and that the resulting skills and knowledge are neither well retained nor easily generalized. We believe that any substantial curriculum design effort would be better advised to concentrate on developing materials that can be comprehended by Representational students so that the emphasis is on the opportunity to exercise existing skills and, hopefully, to make the transition to Formal Operations in a natural manner.

In the following section we will illustrate this with an example of the curriculum process we are proposing.

CONSIDERATION OF A SPECIFIC EXAMPLE

In this example we illustrate how we would sequence instruction that would result in a student's acquisition of the basic concepts of a system. For our purpose we assume that the concept of a system is only one of several concepts that are combined with process skills in a hypothetical instructional module on city planning (see Figure 24).

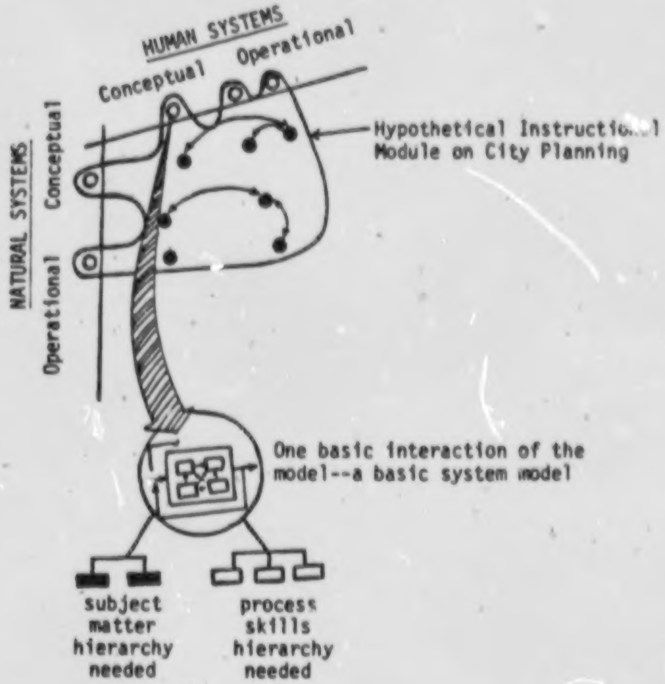

HUMAN SYSTEMS
Conceptual
Operational
NATURAL SYSTEMS
Conceptual
Operational
Hypothetical Instructional Module on City Planning
One basic interaction of the model--a basic system model
subject matter hierarchy needed
process skills hierarchy needed

Figure 24. THE CONCEPT OF A SYSTEM AS A SINGLE COMPONENT OF A HYPOTHETICAL INSTRUCTIONAL MODULE ON CITY PLANNING

This is a difficult and yet instructive concept to consider since it almost makes a circle. In effect, we are asking how the mind would model a very generalized system model. Figure 25 illustrates the model components, transitions, and boundaries that we want the student to be able to understand.

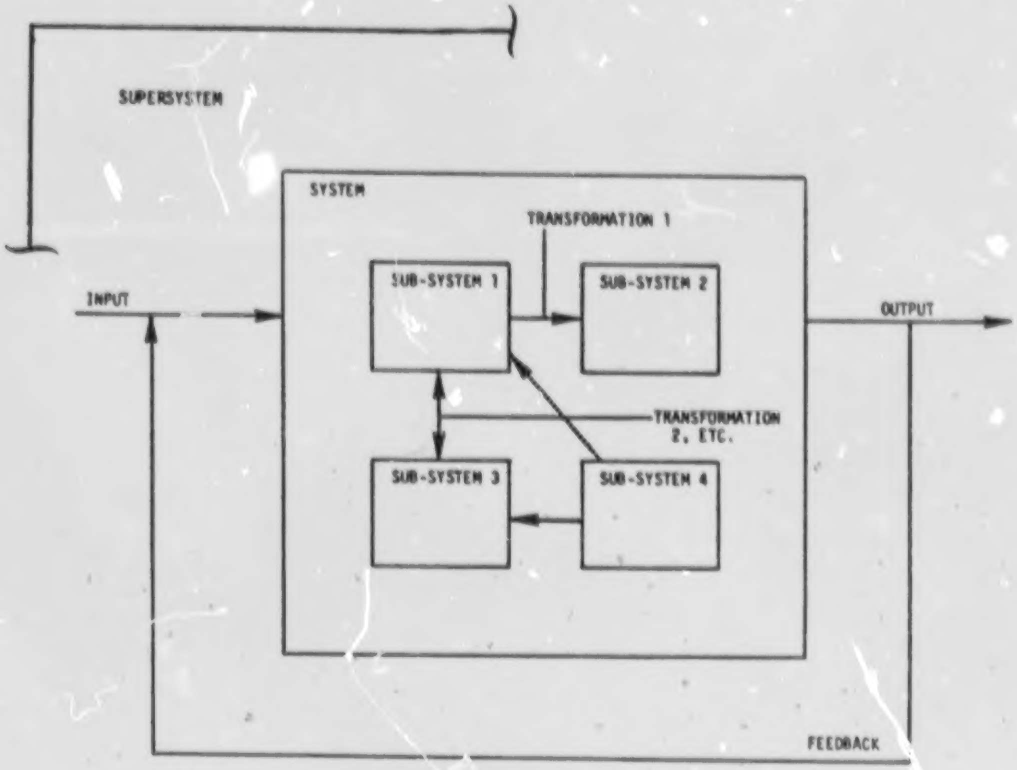

SUPERSYSTEM
SYSTEM
TRANSFORMATION 1
SUB-SYSTEM 1
SUB-SYSTEM 2
INPUT
OUTPUT
TRANSFORMATION 2, ETC.
SUB-SYSTEM 3
SUB-SYSTEM 4
FEEDBACK

Figure 25. BASIC SYSTEM MODEL

We began by realizing that our Basic System Model is a meta-model; it is obviously Formal or abstract. It could be more abstract. For example, we could specify that the inputs or feedback we are interested in involve information rather than some physical form of feedback. Our first goal, however, was to give the model a Concrete form. Obviously, the specific Concrete form chosen depends upon the purpose of the particular curriculum project. For our purposes, we chose a grocery store as our specific example of a concrete system. Accordingly, we modified the system as shown in Figure 26.

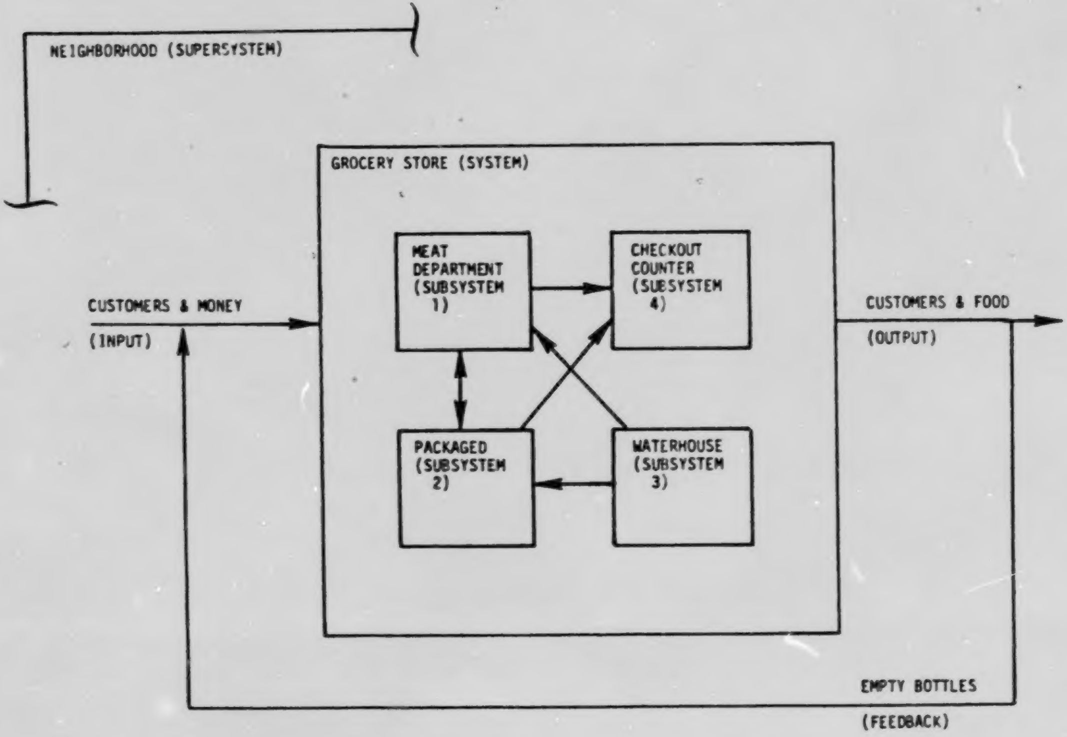

NEIGHBORHOOD (SUPERSYSTEM)
GROCERY STORE (SYSTEM)
MEAT DEPARTMENT (SUBSYSTEM 1)
CHECKOUT COUNTER (SUBSYSTEM 4)
PACKAGED (SUBSYSTEM 2)
WATERHOUSE (SUBSYSTEM 3)
CUSTOMERS & MONEY
(INPUT)
CUSTOMERS & FOOD
(OUTPUT)
EMPTY BOTTLES
(FEEDBACK)

Figure 26. THE GROCERY STORE AS A CONCRETE MODEL OF A SYSTEM

We are sure we can teach any junior high school, high school, college, or adult student to conceptualize a grocery store as a system. In other words, we are sure we can teach any student who is reasonably advanced into the Representational Period to conceptualize a grocery store as a system.

Next we hypothetically place our grocery store at the transition between the Representational Period and the Formal Period and consider what subject matter and intellectual skills hierarchies we could construct to lead the student to our model (See Figure 27). To simplify this example, we will consider only the development of a subject matter hierarchy. We will ignore the actual skills we would want the students to demonstrate in conjunction with acquiring the verbal concepts implicit in the grocery store model. Hence, we will ignore the process hierarchy that we need to construct.

We want the students to develop a Formal concept of a basic system, if possible. To illustrate this we have pictured a Formal version of the basic system model above the grocery store model. In actual curriculum design we would divide this Formal system into a small learning hierarchy, but for our purposes the Formal model will serve to remind us that we will present this Formal model along with our grocery store model in the instructional module to allow and encourage students to make this abstraction if they are ready to do so. We would not, however, design materials that *require* this abstraction or we would risk losing students who were not yet capable of Formal Operations.

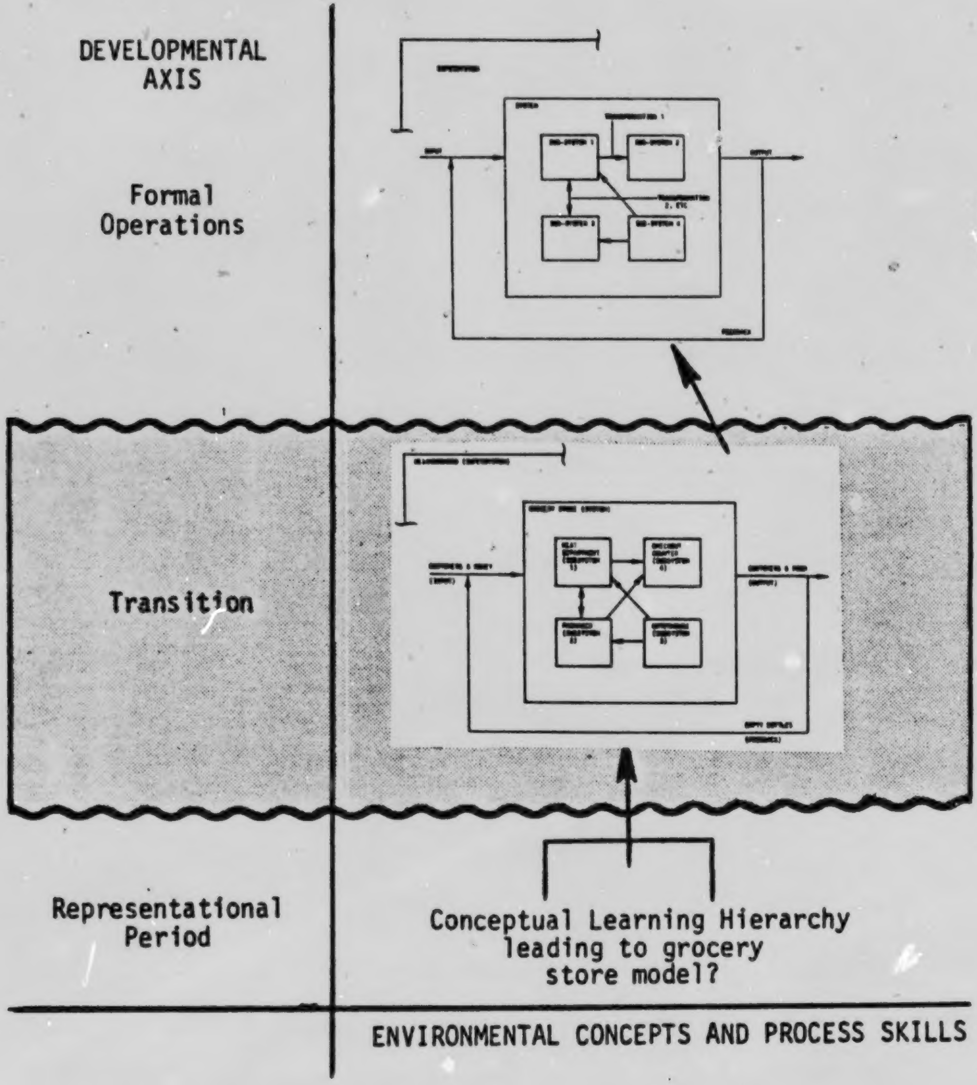
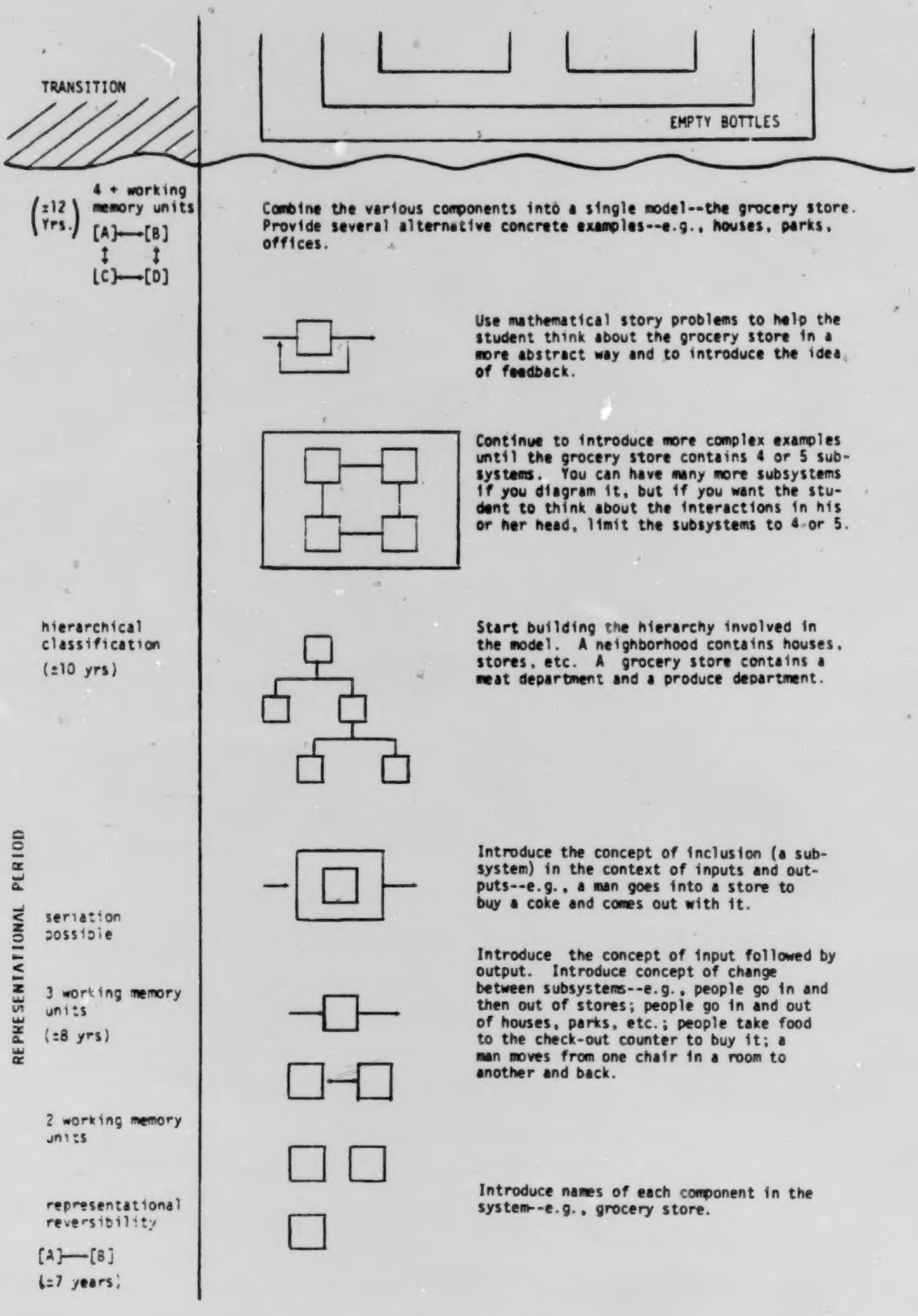

DEVELOPMENTAL AXIS
Formal Operations
Transition
Representational Period
Conceptual Learning Hierarchy leading to grocery store model?
ENVIRONMENTAL CONCEPTS AND PROCESS SKILLS

Figure 27. ENVIRONMENTAL CONCEPTS AND PROCESS SKILLS
(See pp. 101 and 102 for enlarged diagrams.)

We now turn to the development of a conceptual learning hierarchy that will lead to the grocery store model. The major features in such a hierarchy are pictured in Figure 28.


TRANSITION
EMPTY BOTTLES
4 + working memory units
(±12 Yrs.)
[A]⟷[B]
↕ ↕
[C]⟷[D]
hierarchical classification
(±10 yrs)
REPRESENTATIONAL PERIOD
seriation possible
3 working memory units
(±8 yrs)
2 working memory units
representational reversibility
[A]—[B]
(±7 years)

Combine the various components into a single model--the grocery store. Provide several alternative concrete examples--e.g., houses, parks, offices.

Use mathematical story problems to help the student think about the grocery store in a more abstract way and to introduce the idea of feedback.

Continue to introduce more complex examples until the grocery store contains 4 or 5 subsystems. You can have many more subsystems if you diagram it, but if you want the student to think about the interactions in his or her head, limit the subsystems to 4 or 5.

Start building the hierarchy involved in the model. A neighborhood contains houses, stores, etc. A grocery store contains a meat department and a produce department.

Introduce the concept of inclusion (a subsystem) in the context of inputs and outputs--e.g., a man goes into a store to buy a coke and comes out with it.

Introduce the concept of input followed by output. Introduce concept of change between subsystems--e.g., people go in and then out of stores; people go in and out of houses, parks, etc.; people take food to the check-out counter to buy it; a man moves from one chair in a room to another and back.

Introduce names of each component in the system--e.g., grocery store.

Figure 28. SEQUENTIAL DEVELOPMENT OF THE CONCEPT OF A SYSTEM

V. SUMMARY

IMPLICATIONS FOR CURRICULUM DESIGN

Developmental and cognitive models of considerably greater power will be developed in the next years. They should substantially improve the process of curriculum design. Available models, although still in need of further research, nevertheless offer some helpful guidelines. For example, the learning readiness axis presented in this monograph can be used to help in the sequencing of instuctional presentations.

By conceptualizing outcomes in terms of conceptual models rather than specific concepts or even complex skills, the curriculum designer has a powerful tool to use in thinking about instructional objectives and hierarchies.

Those working in the design of materials for high school and college students and adults should be sensitive to the differences between Representational, transitional and Formal operators. Consideration of these differences should be incorporated into curricula by developing materials that present models that can be interpreted in both a Representational and a Formal way.

We believe it would be especially helpful to subdivide all instructional objectives into Representational objectives and Formal objectives (Greeno, 1976). This would force designers to focus on exactly what type of task or subject matter they are asking students to study and on when to begin introducing Formal concepts. It would also help teachers using the materials to decide what modules to assign to which students. Likewise, these objectives would allow teachers to do formative testing to determine their students' overall cognitive progress.

A major implication of the developmental research is that current treatments utilized to teach problem-solving skills should be reconceptualized in terms of the Representational/Formal distinction. Thus, programs currently attempting to teach specific problem-solving or modeling skills might be better advised to seek the broader goal of moving their students from the Representational Period to the Formal Operations Period.

IMPLICATIONS FOR THE ALLOCATION OF INSTRUCTIONAL EFFORT IN ENVIRONMENTAL EDUCATION

We believe that current research supports the idea that any concept or skill can be taught at almost any age beyond, say, three years of age. The instructional costs in terms of time and effort used, and the instructional benefits in terms of retention and generalization decline, however, as one tries to teach students concepts or skills that are not cognitively matched with the developmental period they are currently in. Thus, unless extraordinary circumstances dictate an exception, the implication seems to be that environmental educators ought to concentrate on presenting Representational models to grade school and high school youth. Indeed, given the assumption that many college students and adults have not yet entered Formal Operations, we recommend that nearly all environmental instruction offered to a general public be comprehensible in strictly Representational terms. Our review of selected high school and college environmental materials indicates that these materials are predominantly Formal in their vocabulary, presentation, and objectives. Consequently, these materials are probably not fully communicating with their intended audience.

This is not to suggest that Formal concepts should not be taught. The very nature of environmental studies involves the integration of abstract variables in complex models. It also involves the consideration of hypothetical possibilities. Thus, in a broad and very essential way, successful environmental education is critically linked to the development of Formal Operational thought. We recommend that special attention be given to the transition from Representational thinking to Formal thinking. This can probably best be done by presenting a good Representational model and then discussing it alternately in both Representational and Formal terms. The transition process seems likely to be further facilitated if the instructor encourages peer group discussion and personally advocates a Formal way of conceptualizing the situation.

IMPLICATIONS FOR THE TRAINING OF TEACHERS

The implications of the developmental literature for the training of teachers are profound. Formal Operators commonly use words, concepts, and models that Representational students can not fully comprehend. This results in poor communication and frustrated students. This problem is especially acute since Formal Operators typically forget that they were once Representational and, hence fail to comprehend fully the problems of the students. Furthermore, since they may fail to appreciate the problems associated with the transition from

Representational to Formal Operations, teachers may fail to present models in both Representational and Formal ways and to emphasize the dual nature of such models.

All teachers working with students eleven years old, or older, including those working with adults, should know the basic findings of developmental psychology. Moreover, they should receive specific practice in the application of these findings to teaching situations. This should result in teachers who are able to distinguish between and use Representational and Formal objectives and who can use models that can be interpreted in both Representational and Formal ways. Moreover, teachers should be very aware of the value of peer group discussion and the teachers' advocacy of Formal interpretations as ways of encouraging the transition from Representational to Formal thought.

RECOMMENDATIONS FOR FUTURE RESEARCH AND DEVELOPMENT

Based on the review of the developmental, learning, and environmental education literature summarized in this monograph, we recommend the following:

> *Continuing Attention to the Progress of Developmental Research.* An ongoing program designed to monitor and summarize the developmental and cognitive research relevant to the curriculum design should be established. This program should produce specific recommendations to guide curriculum designers in environmental education. We believe that the information processing approach should be very carefully monitored. We suggest that especially fruitful results will be forthcoming during the next five to ten years.

Demonstration Materials Embodying Developmental Findings.

Several units of environmental materials, preferably targeted at high school, college, and adult audiences, should be developed. These materials should embody the findings described in this monograph. The units should be tested and the results should be disseminated to others working in environmental education curriculum design and development.

Instructional Modules and/or Workshops for Teachers and/or Curriculum Personnel.

Materials should be developed that will inform teachers and curriculum designers about the implications of developmental research. These materials should highlight the differences between Representational and Formal objectives and should acquaint the teachers with the techniques appropriate to Representational, transitional, and Formal students. The materials should include instruction and practice in using models that can be interpreted in both Representational and Formal ways and in using peer group discussion and personal advocacy to encourage the full transition to Formal thought.

APPENDICES

A. A REVIEW OF SELECTED DEVELOPMENTAL TASK SEQUENCES

B. A SPECULATIVE EXTRAPOLATION OF AN INFORMATION PROCESSING MODEL OF DEVELOPMENT

APPENDIX A:

A REVIEW OF SELECTED DEVELOPMENTAL TASK SEQUENCES

In the body of this paper we have indicated that the basic strength of the developmental approach is the descriptive data drawn from a number of problems that Piaget and others have set for children. Children consistently move from one type of solution to another. Within a given period, which is only very loosely correlated with the age of a child, the child will tend to approach a variety of different problems with an overall strategy that reflects the modeling capability, executive strategy, and/or working memory units that the child has available during that period. For the convenience of those not familiar with these problems, we have summarized some of the most important ones in this appendix.

In each case the problem is presented as a column on a chart, and the column is referred to as a task sequence. The solutions offered by the student in successive periods are numbered and referred to as successive responses in a task sequence. The strength of the developmentalists' claims rests on data indicating a great majority of children work through these task sequences in the order given. In other words, the children attempt to solve the problem with Response 1 before attempting a Response 2 solution.

This appendix is divided into three sections, each concerned with five tasks. Each set of five tasks is described, and then summarized on a chart. In each case the chart follows the task descriptions and can be folded out and studied as the task descriptions are read.

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TASK 1: CONSERVATION OF LIQUIDS

Overview

The "Water Task" is perhaps the best known of Piaget's many ingenious tasks (Piaget, 1965). The child is presented with two flasks of identical dimensions. An amount of water is poured into one and the child is asked to put an equal amount into the other. A third flask which is much taller and narrower is added to the array and one of the original flasks is emptied into it. The child is asked whether there is more water in this new flask, whether there is less water, or whether the amount remains the same. Any answer is probed to discover the criteria for the decision. A fourth flask which is wide and short is added to the display and the procedures are repeated. Alternately, a number of tiny cups or unusual shaped bottles may be filled. In all cases, the child is asked to judge the equality of amount and to explain his or her reasoning.

Response Sequence

1.1. The child reports a change in the amount of water with each transformation.

1.2. The child reports equality in single slight transformations, but inequality in multiple transformations.

1.3. The child reports no change in amount, regardless of the number of transformations or the degree to which the transformations involve radical perceptual changes.

Interpretation:

Very young children are not acquainted with the idea of equality of amount. If a young child declares that there is more water in the tall narrow flask, then to a probe he or she may respond, "...there is more because I want there to be more..." With differing proportions in the dimensions of the flasks, the young child picks one salient dimension and bases his or her conclusion on its polarity. That is, water that is tall must also be water that is "more."

Piaget describes this overgeneralization of one attribute "transductive" logic, in contrast to the adult forms of inductive and deductive logic. In inductive thought, particular events are gathered together into a rule or principle while in deductive thought principles are applied to a particular event. The child, it appears, leaps from particular to particular without regard to all of the salient particulars. The child thinks, "If this water is greater in any respect, and it is taller, then the water must be greater in all respects--so there is more."

Later responses indicate the beginning and solidification of the compensation principle. When the child realizes that both height and cross-sectional area are critical to volume, then s/he begins to coordinate the two dimensions, allowing changes in height to be equalized by changes in width. In the intermediary response (1.2), this principle is fragile. Extreme transformations provide sufficient stress to cause the child to return to the earlier response (1.1).

When the child achieves necessary conservation (1.3), he or she is fully capable of applying the compensation principle to this and other tasks. Achievement of necessary conservation of continuous (vs. discrete) quantities marks full entry into the Representational Period of thought. Because the water task is most difficult, it is often employed as a measure of "full" Representational thought. When the child can employ compensation in this task, then he or she most certainly will be able to do it in any other task with compensating attributes open to observation.

Some developmental theorists are suspicious of this final interpretation. Pascual-Leone (in Case, 1974) reports that the usual argument employed by children giving response 1.3 is that the amount is equal because nothing was added or spilled. Pascual-Leone suggests that children are not necessarily able to employ compensation logic as a problem-solving tool until much later.

The problem of interpretation hinges upon the nature of volume. Piaget contrasts *volume*, as a Representational concept, with *density*, as a Formal concept (cf. Sinking and Floating, Task 6). He proposes that the volume of a substance can be observed. Indeed, volume can be measured in a single operation. Density, on the other hand, cannot be observed nor can it be measured in a single operation. Density is always an abstract relationship between the weight and volume of a substance.

Regardless of disagreements in interpretations, the water task is a source of direct inference for curricula. For whatever exact reasons, tasks and problems which require the understanding of continuous (vs. discrete) processes and quantities will not be fully understood until the child is strongly rooted in the Representational Period.

TASK 2: CLASSIFICATION

Overview

Classification tasks explore the child's ability to sort multi-attribute materials. The child is presented with an array of blocks, for example. Some blocks are red and others are blue. Some blocks are square while others are triangular. Some blocks are thin and others are thick. The child is asked to make two groups of blocks so that all the blocks in each group "go together" in some way and so that there are no blocks left over. If the child is able to classify the blocks in one way, then the blocks are regrouped and the child is asked to "think of a new way." An extension of the task uses a set of ten or so blocks. All are triangles but eight are red and two are blue. After the experimenter is satisfied that the child recognizes these attributes, he or she asks, "Are there more red blocks or are there more triangles?" (Piaget, 1965)

Response Sequence

2.0. The child forms patterns or chains of items without extracting a single criterion to apply across all items.

2.1. The child is able to group the items with a single criterion but cannot regroup them in a new way.

2.2. The child is able to group the items in more than one way. But he or she responds that there are more red blocks than triangular blocks.

2.3. The child is able to group the items in more than one way and he or she responds that there are more triangles because "...they are all triangles..."

Interpretation:

The Classification Task demonstrates several traits of thought Piaget has isolated in young children. Of particular importance is the trait of "centering." In early efforts to classify a set of materials, the child centers upon an item and then links that object to the next. Later the child centers upon a single criterion and is unable to recenter and to regroup the objects in a different manner. In the hierarchically organized task, the child centers upon the abundance of red blocks without consideration of triangularity. In a sense, classification summarizes the concept of decentering--the ability to look again at a set of materials in a new way.

The ability to decenter develops across tasks. While decentering skills are particularly clear in classification tasks, they help explain the child's responses to water conservation tasks as well. That is, the child usually centers upon the height of the water to the exclusion of other dimensions.

In curriculum development, the educator ought to be cautious about activities and materials that require multiple and hierarchical classification skills. Children will be able to understand a particular level within a hierarchy long before they can place their information into a hierarchical context. When multidimensional activities are planned, care should be taken to center the child upon the most salient aspects of the activity.

A recent concern in developmental research has been the child's response in classifying ambiguous or "fuzzy" sets of objects (Rosch, et al., 1976). Piaget defines a class with the properties of *intension*, a set of defining criteria, and *extension*, a set of items which instantiate the criteria. While this definition fits the case of geometric figures quite well, one is hard pressed to construct a neat intension for the set we agree upon as "furniture." The reader who has attempted to organize a filing system in an elegant hierarchy can appreciate the concerns with Piaget's simple definition of class.* Thus, a major limitation for Piaget's classification tasks is that analogies can be drawn only to situations where orderly hierarchies and complete intensions apply. While mathematical concepts may be neatly ordered, political and social concepts remain problematic.

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*This example acquired from James Spear.

TASK 3: SERIATION

Overview

Piaget explored children's abilities to order and coordinate ordered sets of objects as an element in the development of a number of concepts (Piaget, 1965). The materials for the seriation task were commonly ten dolls and ten balls. Each set of ten objects was designed so that the increments of increase in size were equal and the largest object was twice the size of the smallest one. Children were presented with the dolls and asked to produce an ordered display. A set of canes was presented with the same request. Children were asked then to choose the cane that "goes with" a particular doll. Later, the child was asked to make appropriate pairings, when the order of canes was reversed with respect to the dolls. Probes were employed, as usual, and careful notes were taken to document the procedures employed by the children in ordering the sets.

Response Sequence

3.1. The child is unable to order the mid-range items. Very large and very small items are located at the extremes, but precise order is attempted through "perceptual guesses."

3.2. The child is able to order each set with many trials and errors. The child cannot consistently pair items from each set, particularly if the order of one set is reversed with respect to the other set.

3.3. The child is able to order each set easily. A procedure of binary comparisons is employed efficiently. By assigning cardinal numbers to each set, the child is able to match ordinal pairs between the sets.

Interpretation:

Seriation tasks like this one are a part of Piaget's examination of number concept development. The youngest children are unable to employ a procedure but rather depend upon perceptual estimation. Because the increments are small, this strategy is ineffective. When ordinal techniques emerge, they are fragile and many errors occur (3.2). Later, the child approaches the set of items by individually comparing each added item to the array he or she has completed.

Consistent with other tasks (cf., Task 5 - Water Level), extreme conditions are correctly interpreted by the child. In this task it is the middle range of judgments that causes problems. Very young children can order a set of four or five dolls with no problem. With this task more than most others, it is the selection of materials that is most critical in producing the responses. It is not until the Representational Period that children develop the kinds of algorithms or binary strategies necessary to avoid the perceptual impossibility of this task. Not even an adult could store and compare the images of twenty objects.

This task, like many natural problems, has a potential for information overload. It is characteristic of the Representational Period to invent algorithms or rule-governed procedures to avoid overload. Implicit in the responses of the oldest children is the definition of Piaget's quantum unit of intelligence, the scheme. Development is the incorporation of more sophisticated schemes or strategies into the child's intellectual repertoire.

In examining number, Piaget is most concerned with how children apply mathematics to solve a problem. As we see here (and in Conservation of Number Task, 4), "knowing" how to count to ten (which most children can demonstrate by the age of five) is not the same as "knowing" how to apply cardinal numbers to an ordinal vector in order to coordinate that vector with a second one. In a sense, Piaget is conservative in granting children intellectual skills. When a child notices that counting will help in this task, we can rest assured that he will do so in most relevant circumstances.

TASK 4: CONSERVATION OF NUMBER

Overview

The Conservation of Number Task presses the child's concept of amount in the case of discrete quantities. This task is complementary with the conservation of liquids task. Many variations of the number task have been explored. One employs two sets of disks of differing sizes. A line of small disks is formed for the child, who is now asked to construct a second line of disks "so that there will be just as many disks." The experimenter transforms the display, alternately spreading out and compacting the disks, and then probes to see if equality prevails. A second variation employs the apparatus and procedures of the Water Conservation Task with beads substituted for water. Predicting the number of flowers needed to fill a set of vases is a third variation used to explore early development. Across all variations the responses are parallel to the following.

Response Sequence

4.1. The child is unable to maintain equality through transformations. When items are wide spread, the child reports that there are more of them.

4.2. The child is able to maintain equality through a few mild transformations, but returns to 4.1 in the face of radical or multiple changes in the array.

4.3. The child is able to conserve number through all changes in the array, and reasons that the number of objects is necessarily the same.

Interpretation:

The Number Conservation Task is interpreted much in the spirit of the water conservation task. Younger children produce perceptual guesses and do not apply the numbers they are usually able to recite by this time. Intermediary responses are fragile forms of the final stage.

Ostensibly, the Number Conservation Task requires the same kinds of skills as the Water Conservation Task, yet the development of water conservation occurs much later than number conservation. This misalignment of development is not well understood nor well explained by Piaget, although he does offer a name for it: decalage. While the problem of decalage is a significant one for the predictive power of Piaget's theory, we find his documentation of these events useful in its own right. In many relevant domains, the educational practitioners can return to Piaget's observations and compare their concept or activity directly to his data. We feel that the misalignment problem is a significant one, to be sure. Decalage between tasks within domains can be interpreted as a warning signal that all inferences to new situations must be treated as approximations or hypotheses. Only in field testing will the curriculum developer be certain that inferences are correct.

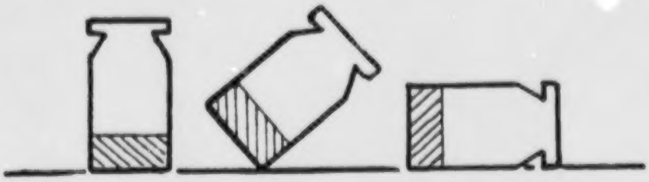
TASK 5: WATER LEVEL

Overview

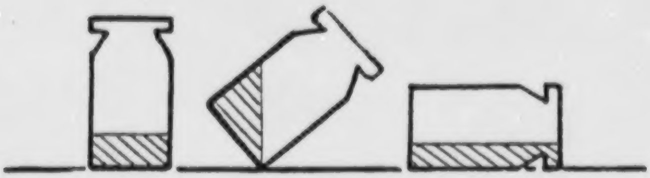
The "Falling Bottle" task is one of the more vivid demonstrations of the child's development of spatial relationships. The child is presented with a bottle partially filled with water. A second bottle is presented, empty but otherwise identical. The second bottle is tilted to a 45 degree angle and the child is asked to predict where the water line would be if the water from the first bottle were poured in. The empty bottle is then set on its side and the child is asked to indicate where the water line would be in this case.

Response Sequence

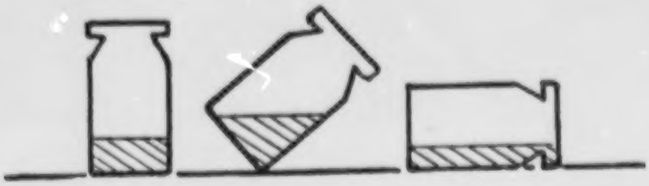
5.1. The child predicts that the water level will remain parallel to the bottom of the bottle.



5.2. The child predicts a horizontal water level for the bottle resting on its side, but predicts a vertical line for the tilted bottle.



5.3. The child predicts horizontal water levels for both changes.



Interpretation:

It is Piaget's hypothesis that quite straightforward and ordinary "facts" about the world are slow to develop in children. What appears to be a simple principle for adults is disorienting in early and even middle childhood. Spatial relationships are learned after several years of interaction and experimentation.

Preoperational thinkers (ages two to seven or eight) are particularly vulnerable to dynamic transformations. In this task, as well as many other tasks, the child appears to treat each episode as an independent event--as a still photograph. Consistent with this interpretation is the order of discovery. The older child solves the end state--the horizontal condition--before finally solving the intermediary state.

The process Piaget calls assimilation is clearly evident in some typical responses to the water level task. Many young children indicate that there will be very little water left clinging to the bottom of the horizontal bottle. To the question, "Why is there so little water?" they respond, "...because it has spilled out...." Even though children know the experience of spilling, they still "force" this task into a more primitive model of the world.

These five tasks are illustrated in Chart A-1: Tasks that Contrast Preoperational and Representational thought.

CHART A-1: TASKS THAT CONTRAST PREOPERATIONAL PERIOD AND REPRESENTATIONAL THOUGHT.

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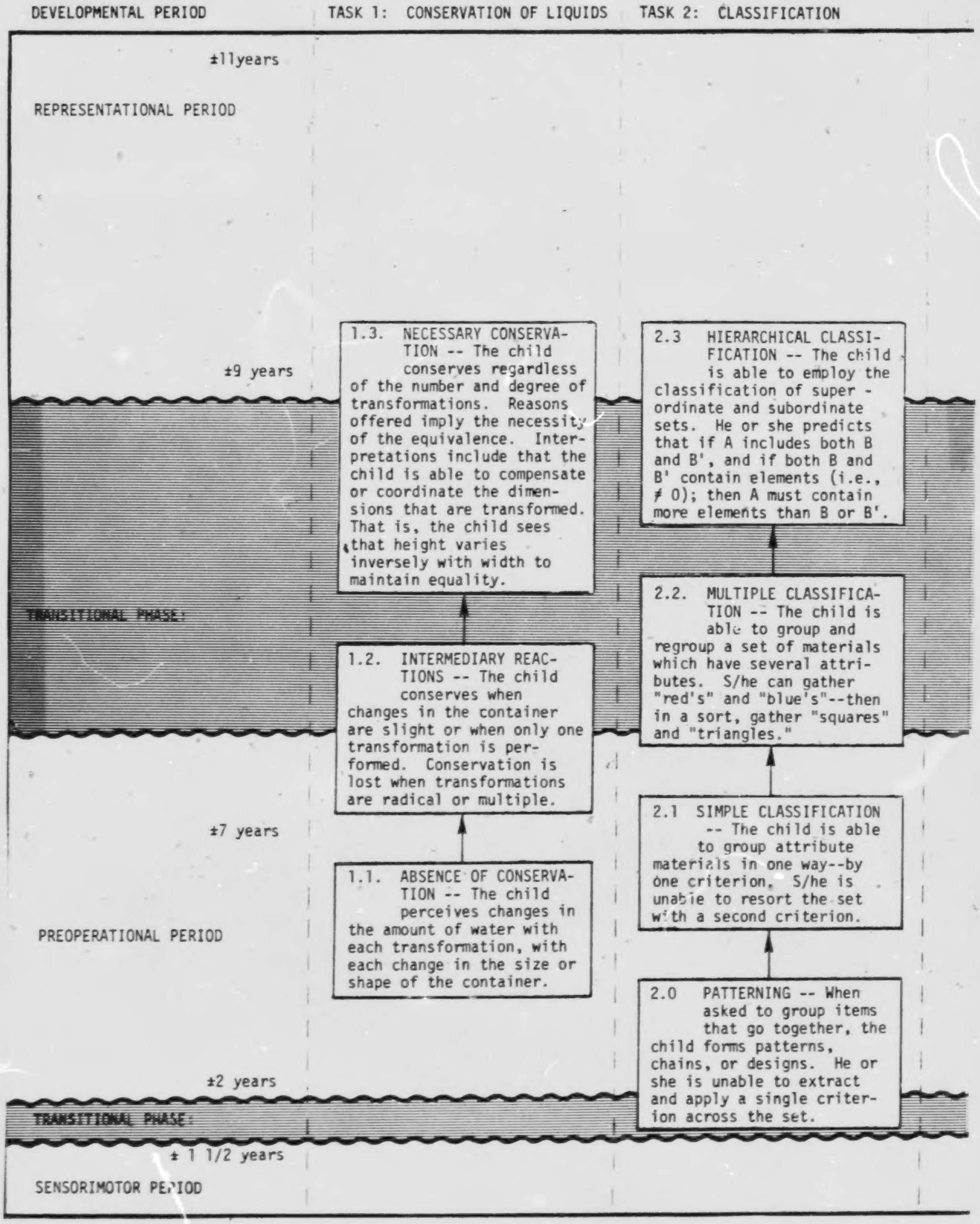

DEVELOPMENTAL PERIOD
TASK 1: CONSERVATION OF LIQUIDS
TASK 2: CLASSIFICATION
±11years
REPRESENTATIONAL PERIOD
±9 years
TRANSITIONAL PHASE:
±7 years
PREOPERATIONAL PERIOD
±2 years
TRANSITIONAL PHASE:
± 1 1/2 years
SENSORIMOTOR PERIOD

1.3. NECESSARY CONSERVATION -- The child conserves regardless of the number and degree of transformations. Reasons offered imply the necessity of the equivalence. Interpretations include that the child is able to compensate or coordinate the dimensions that are transformed. That is, the child sees that height varies inversely with width to maintain equality.

1.2. INTERMEDIARY REACTIONS -- The child conserves when changes in the container are slight or when only one transformation is performed. Conservation is lost when transformations are radical or multiple.

1.1. ABSENCE OF CONSERVATION -- The child perceives changes in the amount of water with each transformation, with each change in the size or shape of the container.

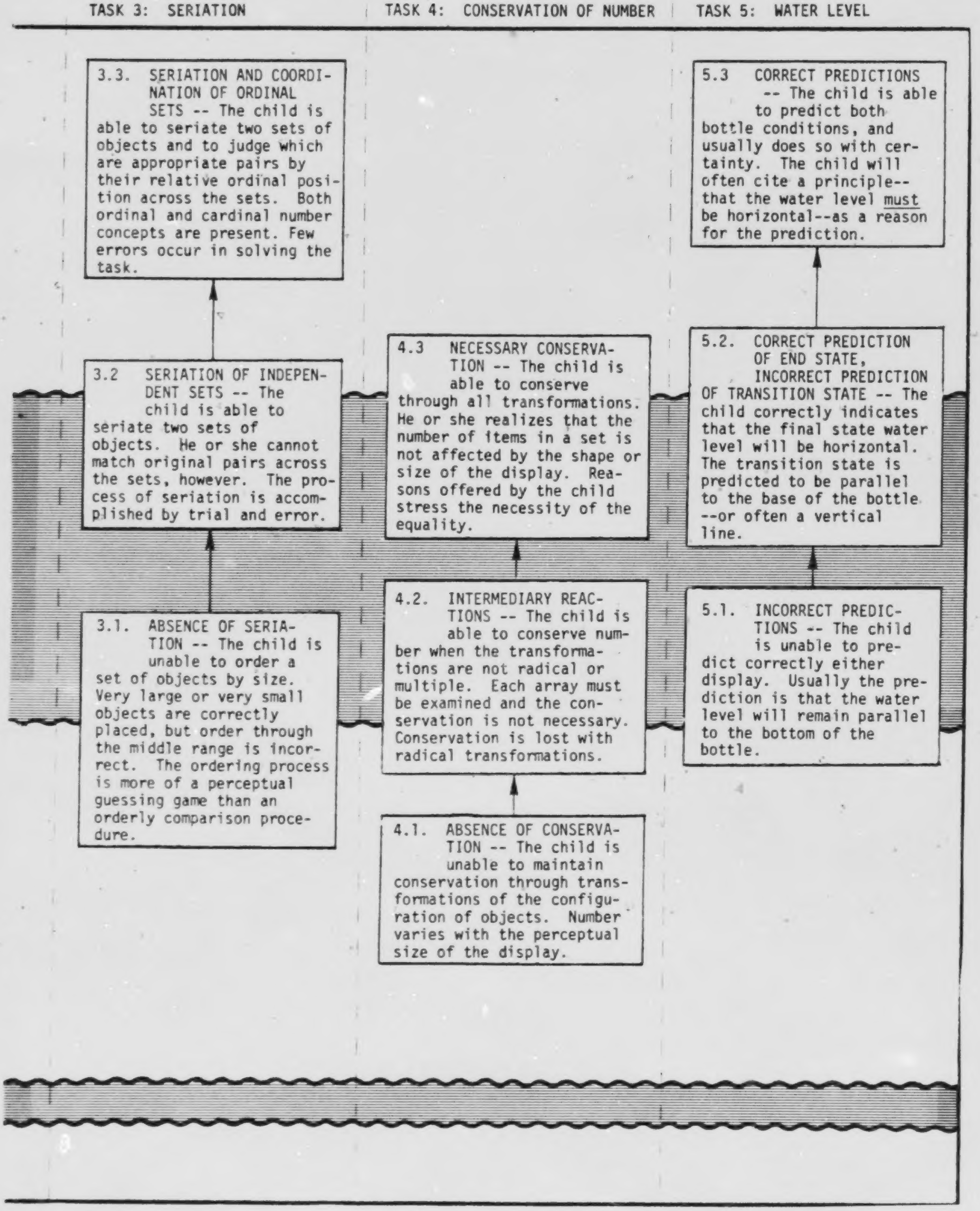
2.3 HIERARCHICAL CLASSIFICATION -- The child is able to employ the classification of super - ordinate and subordinate sets. He or she predicts that if A includes both B and B', and if both B and B' contain elements (i.e., ≠ 0); then A must contain more elements than B or B'.

2.2. MULTIPLE CLASSIFICATION -- The child is able to group and regroup a set of materials which have several attributes. S/he can gather "red's" and "blue's"--then in a sort, gather "squares" and "triangles."

2.1 SIMPLE CLASSIFICATION -- The child is able to group attribute materials in one way--by one criterion. S/he is unable to resort the set with a second criterion.

2.0 PATTERNING -- When asked to group items that go together, the child forms patterns, chains, or designs. He or she is unable to extract and apply a single criterion across the set.

CHART A-1: TASKS THAT CONTRAST PREOPERATIONAL PERIOD AND REPRESENTATIONAL THOUGHT. {continued from previous page}



TASK 3: SERIATION

3.3. SERIATION AND COORDINATION OF ORDINAL SETS -- The child is able to seriate two sets of objects and to judge which are appropriate pairs by their relative ordinal position across the sets. Both ordinal and cardinal number concepts are present. Few errors occur in solving the task.

3.2 SERIATION OF INDEPENDENT SETS -- The child is able to seriate two sets of objects. He or she cannot match original pairs across the sets, however. The process of seriation is accomplished by trial and error.

3.1. ABSENCE OF SERIATION -- The child is unable to order a set of objects by size. Very large or very small objects are correctly placed, but order through the middle range is incorrect. The ordering process is more of a perceptual guessing game than an orderly comparison procedure.

TASK 4: CONSERVATION OF NUMBER

4.3 NECESSARY CONSERVATION -- The child is able to conserve through all transformations. He or she realizes that the number of items in a set is not affected by the shape or size of the display. Reasons offered by the child stress the necessity of the equality.

4.2. INTERMEDIARY REACTIONS -- The child is able to conserve number when the transformations are not radical or multiple. Each array must be examined and the conservation is not necessary. Conservation is lost with radical transformations.

4.1. ABSENCE OF CONSERVATION -- The child is unable to maintain conservation through transformations of the configuration of objects. Number varies with the perceptual size of the display.

TASK 5: WATER LEVEL

5.3 CORRECT PREDICTIONS -- The child is able to predict both bottle conditions, and usually does so with certainty. The child will often cite a principle--that the water level must be horizontal--as a reason for the prediction.

5.2. CORRECT PREDICTION OF END STATE, INCORRECT PREDICTION OF TRANSITION STATE -- The child correctly indicates that the final state water level will be horizontal. The transition state is predicted to be parallel to the base of the bottle --or often a vertical line.

5.1. INCORRECT PREDICTIONS -- The child is unable to predict correctly either display. Usually the prediction is that the water level will remain parallel to the bottom of the bottle.

TASK 6: SINKING AND FLOATING

Overview

The Sinking and Floating Task developed by Inhelder and Piaget (1956) is one of the most delightful tasks for experimenters and children. A bathtub suffices as a laboratory, and additional materials can be found around the house. The child is presented with an array of objects. Some are relatively dense but light in weight--such as a safety pin. Other objects are not as dense but much heavier than the pin--such as a medium sized chunk of wood. To complete the set, items are included that are both heavy and dense (such as a paperweight) that are both light and less dense (such as a piece of styrene plastic) and that have unusual shapes (such as a sieve and a cup). The child's task is to predict and explain how each of these objects will behave when placed in the water.

Response Sequence

6.1. The child is unable to predict which objects will sink or float. The child may decide that large (in volume) or heavy objects will sink and when these predictions are tested, the child can not remove the contradictions in the predictions. Animistic qualities are often attributed to the objects (e.g., "...it sinks because it is tired...").

6.2. The child attempts to remove contradictions in predictions by seeking to employ other attributes of the objects in addition to weight and size. Often the substance of the object is employed as a criterion (e.g., "...because it is iron..."), but this criterion is also insufficient.

6.3 The child orders (seriates) the objects by weight or size, but is unable to coordinate these two attributes as a single variable, density. The wood floats "...because there is air in it..." is a typical explanation.

6.4 The child is able to coordinate weight and volume to successfully predict which objects will sink and which will float. The Child's conclusions are constrained to the set of objects with which he or she has experimented. The relationship of density to flotation is explained empirically rather than logically.

6.5. The child is able to abstract a general law of flotation: objects that have a density less than that of the medium in which they are placed will necessarily float. In addition, displacement volume must be included in computing the density of closed objects (e.g., cups).

Interpretation:

The distinctive feature of the task is that the salient variable necessary for prediction and explanation is not open to direct observation. Density is the ratio of an object's weight to its volume. While both volume and weight can be observed, density must be hypothesized in some symbolic sense.

Young children center upon one of the two observable criteria and fail to predict an object's behavior in water with any consistency. In lieu of later abilities to produce an interaction variable, they muddle through their predictions and commonly include animistic attributes of the objects as an explanation of inconsistent results.

Older children realize that weight and volume alone will not suffice. Without the ability to isolate density, they search for other criteria such as the material of which the object is made. Because material and density are related, "solid" objects can be classified. Problems arise with the unusual shapes that are "hollow," such as a metal cup.

As the child approaches Formal thought, he or she begins to realize that observed attributes can be combined to produce hypothetical variables. Density first appears as an empirically derived explanation. That is, while the child can explain the behavior of each object, new objects added to the array need to be tested. The child's procedure is not generalizable--which is to say, not entirely Formal, logical, and necessary.

The final response pattern demonstrates achievement of full Formal Operations. In order for a child to fully understand the Sinking and Floating Task, he or she must explain the necessity of flotation when the density of the object is less than that of the medium.

In this task, intermediary responses 6.2 to 6.4 continue for several years. These responses are of special interest because they are Representational strategies applied to a Formal task. This same plateau is observed across other Formal tasks such as the Bendability Task (Task 7).

Representational strategies, wnen employed in Formal tasks, result in partially correct solutions. The problem that the Representational child encounters is generalizability. When the child predicts that wood will always float and steel will always sink, then he or she is correct most of the time.

One possible implication of this task for education and curriculum development is that Formal activities and ideas be withheld until early adolescense. We offer two qualifications, however. First, it is important to realize that Representational skills are sufficient for understanding many common porblems early adolescents will encounter. That is, if we constrain the Sinking and Floating Task to solid objects (and exclude water-logged and unusually dense woods), then the student will be able to solve the task and satisfy all performance criteria. If a topic is judged to be critical, then specific competencies can be expected before a full and Formal understandin[illegible] the topic occurs. In education and curriculum development, the critical work is in identifying specific competencies, since any fully specified topic area will normally require some Formal skills for a "full" understanding.

A second concern in witholding topics is the development of Formal thought itself. Children need to struggle with problems beyond their abilities in order to grow. Thus the teacher or curriculum designer needs to balance practical demands with challenges to assure a balance between immediate success and cognitive development.

TASK 7: BENDABILITY OF RODS

Overview

In order to explore the child's ability to isolate and control variables, Inhelder and Piaget (1956) presented children with a Bendability Task. The child is given a set of rods, unit weights, and a device to clamp the rods in a horizontal plane (see Figure A-1). The rods differ in material (steel and bronze), cross-sectional area and cross-sectional shape (circular, rectangular). With a device like the one shown, the child is able to adjust the length to which the rod extends unsupported. The child is asked to predict and explain the conditions that affect the bending of the rods.

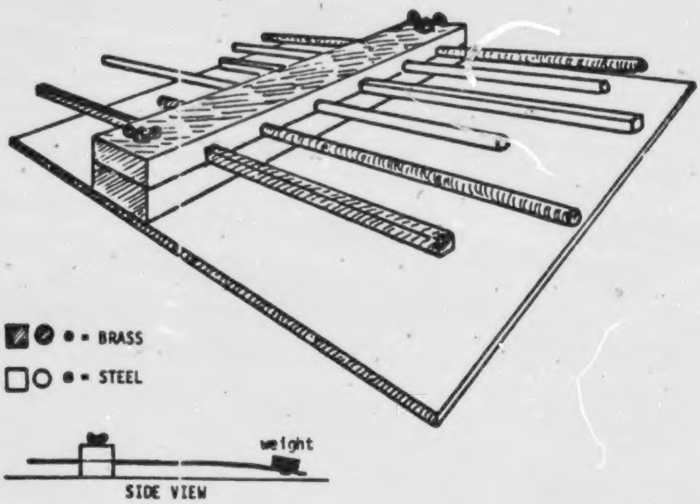


Figure A-1. A DEVICE USED IN THE BENDABILITY TASK

Response Sequence

7.1 The child experiments with the apparatus in a haphazard manner. There is no attempt to classify the kinds of rods and explanations often include attributes of animism (e.g., "...the rod bends because it wants to...") or egocentricism (e.g., "...because I want it to...").

7.2 The child seriates the rods by different attributes (length, material, etc.) but does not coordinate any of the dimensions or hold one constant while testing another. While the child may conclude that increased length predicts increased bendability, the evidence may be the difference in flexing of a short thick rod and a long thin one.

7.3 The child begins to coordinate dimensions, noting that both thin and long rods bend more, for example. In experimenting, variables are not controlled and these conclusions rest upon incomplete evidence even when the child predicts correctly.

7.4 The child begins to control some of the variables and isolate some of the salient attributes of the rods and their placement. Explanations are empirical and incomplete.

7.5 The child controls each variable in turn and arrives at a complete and necessary explanation of the task.

Interpretation:

In the Sinking and Floating Task, the child was required to isolate the Formal concept of density and the relationship between the observed attributes of size and weight. In this task it is the concept of flexibility that is being examined. In order to predict and explain the behavior of the rods, the child must identify and isolate five variables: weight, length of extension, cross-sectional area, cross-sectional shape, and kind of metal.

Interpretations of this task parallel the interpretations of the Sinking and Floating Task. Each response is a categorically closer approximation of the Formal and complete understanding of the task. The intermediary responses 7.2 to 7.4 are reflections of Representational strategies employed in a Formal task. Again these responses often lead to correct answers, but they do not result in exhaustive or general conclusions about flexibility.

The Bendability Task directly concerns the control of variables and the ability of a child to design an experimental procedure amid many competing attributes. The outcome of an experiment is clear; the problem for the child is to attribute the outcome to the correct set of initial condtions.

Children in the intermediary response categories usually confound variables (e.g., they allow two or more to covary unsystematically). While they may report correct relationships, it is the lack of compelling evidence in their experiments that betrays the incompleteness of their procedures.

TASK 8: COLORLESS CHEMICALS TASK

Overview

The child is presented with an array of five bottles of clear liquids labelled A, B, C, D, and X. A spotplate and eyedroppers are provided. The experimenter has previously deposited the correct chemicals in one spotplate so that when s/he adds X in the presence of the subject, a bright color appears. The child is asked to find the combination of chemicals to produce the color.

The chemicals are chosen so that B and D when combined with X produce the color. C is neutral--neither essential nor inhibitory to the successful production of color. A is an inhibiting chemical, precluding the possibility of success when it is a part of any combination. Presuming that the child includes X in every trial (since X was a part of the experimenter's trial), then there are 16 possible combinations to be tested and two (B D X and B C D X) produce color (King and Woodson, 1977).

Response Sequence

8.1. The child combines the chemicals in a random and casual manner. Should a color appear, the child may not be able to reproduce the combination a second time.

8.2. The child combines each chemical with X and may combine pairs of chemicals with X (e.g., ABX, ACX...). The child can reproduce a correct combination, usually B D X. The child often will not produce the three-way combinations with X and thus misses the second solution.

8.3. The child begins with a systematic procedure that breaks down before all combinations have been tried. Either the child claims that the tests are exhaustive when they are not--or is not sure if all combinations have been tried even if they all have been.

8.4. The child proceeds with a systematic testing of all combinations, locates both solutions, and can explain why he or she is sure that all combinations have been tested and only two successes are possible.

Interpretation:

This task demands formal operations for an exhaustive solution. The child must be able to hypothesize all possible combinations of the chemicals and to test each combination. The response sequence reflects the same trends observed in other Formal tasks, although this task is solved a bit later.

The Colorless Chemicals Task is one of the most difficult of the Formal Operational tasks both for adolescents and adults. Because the liquids are colorless, there are no observable clues to guide the subject. Most subjects are tempted to stop without checking all possibilities. Some assume that the order of mixing is important and attempt to check out all permutations rather than all combinations. Other subjects presume that the task involves a knowledge of chemistry. Finally, some subjects do not see that X is required for the solution and explore 32 rather than the intended 16 combinations. All of these factors contribute to the difficulty of the task and cloud interpretation.

Taken in isolation from other demonstrations of Formal Operations, the Colorless Chemicals Task is ambiguous. Among similar tasks, these ambiguities fall into a context. Formal Operations allow a child to detect problems, design experiments, and test hypotheses. The subject who believes that chemistry rather than "thinking" is involved is not oriented toward the Formal hypothetical operations that Piaget and Inhelder sought to describe. Again, Piaget's estimate of children's abilities is a conservative one.

TASK 9: NOELTING'S ORANGE JUICE TASK

Noelting's Juice Task was reported and reinterpreted by Case (1978a). Since we have used the Juice Task to demonstrate Case's neo-Piagetian model (p. 18), we will omit the description and discussion here. The response sequence is illustrated within the Piagetian framework to show the relationship between Piagetian and neo-Piagetian tasks.

TASK 10: SIEGLER'S BALANCE SCALE TASK

Siegler's (1976) Balance Scale Task was employed to illustrate his information processing perspective on Formal Operational thought (p. 21). The response sequence on this task is also illustrated within the Piagetian framework to show the relationship between Piagetian and neo-Piagetian tasks.

CHART A-2: TASKS THAT CONTRAST REPRESENTATIONAL AND FORMAL THOUGHT

DEVELOPMENTAL PERIOD	TASK 6: SINKING AND FLOATING	TASK 7: BENDABILITY OF RODS
FORMAL PERIOD 13+ years	6.5. The child is able to discover the principle of densities and define floating as the case when the density of the object is less than that of the medium. The finding is necessary and general. The "full matrix" of possibilities is explored.	7.5. The child produces a full comibination array of variables, isolates, and demonstrates the place of each in a full explanation of the task.
TRANSITION 11 years	6.4. Child is able to relate weight/volume to the water's weight/volume. The rules derived are specific and empirical (rather than general and necessary). That is, the child draws conclusions about the set of elements with which he or she is experimenting without talking about general findings. The child begins to control variables--testing hypotheses by choosing two objects of equal weight and differing volume. The "full matrix" of possibilities is not explored.	7.4. The child is able to control some variables and arrive at a partial solution to the task. Isolated correct conclusions like "the larger and thicker, the more it resists" are found, but not comprehensive and necessary explanations.
REPRESENTATIONAL PERIOD	6.3. Child begins to seriate weight--or volume--but is unable to coordinate the relationship between the two in any precise way. Sometimes two objects are coordinated but not against the density of the medium, water. Statements like "wood floats because there is air inside it" summarize the child's approaching understanding of density.	7.3. The child at IIB is able to determine the multiplicative combinations of the task's variables. Again the experiments are not controlled--and conclusions are described as "empirical observed relationships" rather than relational principles.
9 years	6.2. The child attempts to remove contradictions from classification, and begins to realize that weight alone is not sufficient --volume alone is not sufficient. Material may be entered as a variable ("because it is iron"), but this too is insufficient.	7.2. This stage is marked by uni-dimensional sorts and quasi-experimental procedures. The child may seriate weights, diameters, and lengths, but does not experiment across (or between) these dimensions with any controls. By covarying dimensions, no conclusions are found--no hint of an "all else equal" hypothesis.
TRANSITION 7 years PREOPERATIONAL PERIOD 3 years	6.1. Objects are not exclusively categorized between the two groups--the child's prediction changes as he or she approaches and reapproaches elements. No stable criteria are developed in testing objects. The child justifies the prediction with his or her wish ("because I want it to") or by attributing animistic qualities to the object ("it will swim").	7.1. The child's efforts to control variables are hampered by weak classification skills and a tendency to attribute events to animistic, final or moral/personal causes. Rods bend because they "have to," "want to," and "they did." Experiments are casual and unordered.

CHART A-2: TASKS THAT CONTRAST REPRESENTATIONAL AND FORMAL THOUGHT

{continued from previous page}

TASK 8: COLORLESS CHEMICAL TASK

8.4. The child systematically tests all 16 combinations of the four chemicals, locates and reproduces both of the color-producing conditions and is certain that all possibilities have been exhaustively tested.

8.3. The child begins with an orderly procedure which breaks down before all combinations have been tested. Some children claim that all possibilities have been tested when, in fact, they have not. Other children are not sure that the tests have been exhaustive.

8.2. The child combines single and paired chemicals with X but usually does not explore the triple combinations. As A result, the child finds one, but not both of the solutions.

8.1. The child combines the chemicals in a random and casual manner Should color appear, the child often cannot reproduce the trail. One or both solutions may not be found.

8.1. The child combines the chemicals in a random and casual manner. Should color appear, the child often cannot reproduce the trail. One or both solutions may not be found.

TASK 9: NOELTING'S ORANGE JUICE TASK

9.5. Children can understand problems involving ratios.

9.4. Children who are 9 to 10 years old notice the extent of the excess or deficit of juice glasses over water glasses on each side. Thus, they succeed on any trial when the correct answer may be determined by deciding which side has the greater excess or lesser deficit. These children continue to fail, however, on items where an understanding of ratio is necessary.

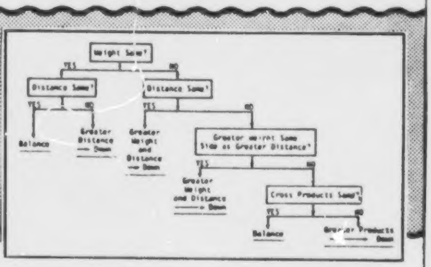
9.3. Between 7 and 8 years, the children notice the number of glasses of water by each pitcher as well as the number of juice glasses. They compare the number of glasses of water and juice on each side and select the side having an excess of juice over water. If both sides have more juice or water, or if both sides are equal, however, they simply guess.

9.2. Children notice not only the presence or absence of juice on each side but also the quantity of juice. Thus, their strategy becomes comparative and they succeed on all trials when the correct answer can be obtained by picking the pitcher surrounded by the greater number of orange juice glasses.

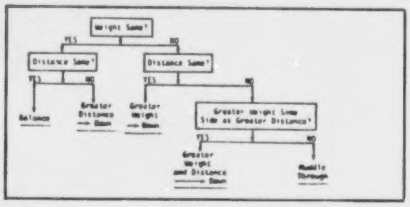
9.1. The children evaluate the glasses in isolation, noticing only one global feature, the presence or absence of orange juice. If only one pitcher is to receive orange juice they can predict successfully, but they resort to guessing in all other cases.

TASK 10: SIEGLER'S BALANCE SCALE TASK

10.4 - Rule IV

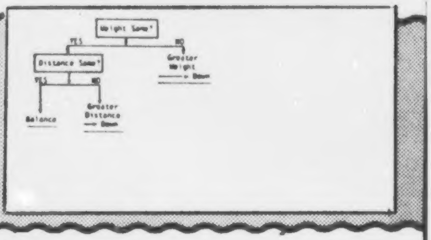

Weight Same?
YES
NO
Distance Same?
YES
NO
Balance
Greater Distance → Down
Distance Same?
YES
NO
Greater Weight and Distance → Down
Greater Weight Same Side as Greater Distance?
YES
NO
Greater Weight and Distance → Down
Cross Products Same?
YES
NO
Balance
Greater Products → Down

10.3 - Rule III

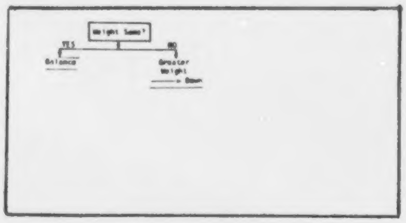

Weight Same?
YES
NO
Distance Same?
YES
NO
Balance
Greater Distance → Down
Distance Same?
YES
NO
Greater Weight → Down
Greater Weight Same Side as Greater Distance?
YES
NO
Greater Weight and Distance → Down
Muddle Through

(See page 23 for enlarged diagrams.)

10.2 - Rule II


Weight Same?
YES
NO
Distance Same?
YES
NO
Balance
Greater Distance → Down
Greater Weight → Down

10.1 - Rule I


Weight Same?
YES
NO
Balance
Greater Weight → Down

TASK 11. PIAGET'S MORAL DEVELOPMENT SEQUENCE

Overview

In an early volume, Piaget (1932) explored the development of moral concepts and moral judgment. Two methods were employed to gather information. First, Piaget observed children in self-directed games such as "marbles" and recorded the way in which rules were used. Second, he presented children with stories in which two behaviors and their consequences were pitted one against another. The child was asked to judge which of the two was the more serious moral infraction. Piaget used stories like this one:

> A little boy who was named Augustus once noticed that his father's ink-pot was empty. One day that his father was away he thought of filling the ink-pot so as to help his father, and so that he should find it full when he came home. But while he was opening the ink-bottle he made a big blot on the table cloth. (1932, p. 122.)
>
> There was a little boy called Julian. His father had gone out and Julian thought it would be fun to play with his father's ink-pot. First he played with the pen and then he made a little blot on the table cloth. (1932, p. 122.)

Response Sequence

11.1. The child demonstrates no clear conception of the rules of a game. Game playing behavior is no different than play behavior in general. The direction of the game varies with the child's wishes and desires.

11.2. The child indicates that rules are absolute and fixed. Even if all players agreed to change a rule, then the resulting game could not be fair because the rule was changed. While rules are recognized in this strict manner, the child interprets the rules in a self-serving manner as the game proceeds. In response to the stories, the child judges that the behavior with the more disastrous consequence is a more serious moral infraction.

11.3. The child continues to view rules as absolute and fixed. He or she is more able to follow rules without self-serving interpretations. Stories are interpreted in the same manner as 11.2.

11.4. The child views rules as guidelines formed by the consensus of the players. Rules can be changed as long as everyone agrees. In interpreting the stories, the child includes the intentions of the actors in judging moral seriousness.

Interpretation:

The first response set is interpreted as a "premoral" level. Very young children are guided by their immediate needs and wishes. Rules are not essential to games, especially when young players are not playing to win but, rather, are enjoying the intrinsic pleasures of exploring the materials.

When rule concepts first emerge, the children regard the rules as fixed and absolute. In applying rules in a game, children interpret the rules in a self-serving manner. Piaget describes this response set as the "egocentric" level because of the children's "cognitive stance" with respect to moral decisions. Whether young children are best described as "egocentric" is a hotly contested issue that we will explore a bit later in this section.

Children of the second and third response set judge the characters in the stories solely by the consequences of their actions. Augustus must be the child who is more wrong because the blot is larger. This is consistent with the Preoperational Period and children's concern with how things look. The children's responses are most likely consistent with their own experiences. Larger messes usually result in louder reprimands from parents.

Response set 11.3 marks an increase in children's ability to follow rules. As we have seen in Representational tasks (1.0 to 5.0), children in the middle childhood years are quite adept at solving problems with strict formulae or rules. This seems to be the social-cognitive style for children of this age as well.

At the onset of the Formal Operational Period, Piaget believes moral judgment changes from an absolute to a relative, contextual model. With increasing ability to incorporate the perspectives of others, children understand that rules are formed and can be changed by the consensus of the players. In interpreting the stories, children consider the intentions of the characters and decide that Julian's behavior is wrong while Augustus' behavior is right and good, regardless of the unfortunate mess. Piaget describes this response set as a level of "genuine cooperation" and "moral relativity" to capture the sophistication of these older children.

As we mentioned earlier, egocentricism is a central theme in Piaget's model of moral development. In fact, egocentricism plays a central role in all areas of cognitive behavior. Inhelder and Piaget (1956) describe three phases of egocentric thought that correspond to and are described by the major developmental periods: Sensorimotor, Representational, and Formal Operations. For example, egocentricism in the Formal Period is described as the child's tendency to view his or her abstract hypothesis as the only possible Formal view. At the Representational level, Piaget has written, "until seven years of age children scarcely know how to have discussions among themselves and confine themselves to contradictory affirmations" (1967, p. 20).

It is most troubling that in his developmental model, Piaget defines egocentricism as a dialectic trait: children are either egocentric or they are not. Recent findings indicate that children appear egocentric in tasks that require sophisticated spatial-perspective skills, while they appear "non-egocentric" in tasks that require less sophisticated skills (cf., Flavell et al., 1968; Laurendeau & Pinard, 1970, for a clear contrast; or Shantz, 1975, for reviews of the issue). Coie, Costanzo, and Farmill (1973) offer evidence that a slow and continuous process of perceptual role-taking ability occurs in childhood.

Recently Flavell commented: "Egocentricism describes the degree to which we are all at risk...." (1977). We agree with Flavell and suspect that the application of egocentricism as the only metaphor of social understanding has been inappropriate. More carefully defined and continuous variables must emerge before we can predict and explain social cognition.

As we remarked initially, Piaget's model is not universally accepted. In this area of moral judgment, the data he gathered are more interesting than the interpretations he made. Researchers who follow in Piaget's tradition are finding similar responses in young children (cf., Task 15, Damon's Positive Justice). Piaget's descriptive account of children's early understanding of rules remains to be explained in a better way.

For education and curriculum development, it makes no more sense to acquaint conservation of liquids with conservation of energy than to acquaint egocentric spatial perspective-taking with egocentric social perspective-taking. To repeat a theme we have mentioned before, all inferences from the Piagetian model *must* be verified with field testing. The most secure inference is to match the proposed curriculum activity or concept precisely with the descriptive data that Piaget provides.

12. KOHLBERG'S MORAL DEVELOPMENT SEQUENCE

Overview

In an effort to extend and elaborate Piaget's work in moral development, Kohlberg (1976) constructed a set of more sophisticated stories. While Piaget's stories contain relatively rudimentary moral distinctions, Kohlberg's stories pose moral dilemmas where one principle of moral action is pitted against another.

To paraphrase Kohlberg's most commonly discussed story, consider the plight of Heinz. Heinz has a wife who is very near death due to a severe illness. Without an expensive drug, she will certainly die. The drug is available but at an extremely high price--ten times the cost of its preparation. Heinz is unable to borrow the money from friends nor is he able to convince the druggist to allow him time to pay even though he has amassed half the needed sum. The druggist claims that since he has discovered the drug, he intends to make money from it. Heinz is desperate. He breaks into the store and steals the drug to save his wife (after Kohlberg, 1971, p. 156).

To his subjects Kohlberg asked, "Should Heinz have done this? Why?" In interpreting the responses, Kohlberg was concerned with the justifications rather than the direction of the judgments. That is, a subject could affirm or deny Heinz' decision and still achieve any level of development. In the response sequence below, we have constructed pairs of responses to demonstrate this point. Because Kohlberg does not report protocols of subjects across all levels, the responses below are hypothetical.

Response Sequence

12.1. The child may respond that Heinz was right to steal the drug because he would feel awful if his wife were to die.

Alternately, the child may respond that Heinz was wrong to steal the drug because he will certainly be punished by the police or by the druggist.

12.2. The child may respond that Heinz was right because he saved his wife and didn't get caught.

Alternately, the child may judge Heinz to be wrong because he will get caught, since the druggist knows of Heinz's need.

12.3. The child or adult indicates that Heinz was right in being a "good husband," since good husbands protect their wives.

Alternately, the child or adult may say that Heinz was wrong because "good people" don't steal.

12.4. The child or adult may claim that Heinz is right in taking the drug because there are laws about druggists making too much profit. Perhaps Heinz was right because a "rule of marriage" is to take care "in sickness and in health."

Alternately, the child or adult may judge Heinz' action wrong because there is a law against theft.

12.5. The adult claims that Heinz is right because he is defending his wife's rights within their social group, or because he has a special social responsibility to his spouse that supercedes the law.

Alternately, Heinz may be judged wrong because he violated the laws which were created to protect the rights of individuals in a social unit.

The critical distinction here is in the definition of a law. At this response level, the law must be defined as a regulation agreed upon by a group of individuals, of whom Heinz is one.

12.6. The adult indicates that Heinz is right in his action because human life is a more important criterion than any other. Not only should Heinz steal the drug for his wife, he should do so for any other human being in need.

Alternately, the adult may judge Heinz to be wrong because in stealing the drug, Heinz traded his wife's life for the life of another person. While Heinz is wrong, the circumstances allow for no positive moral actions.

Interpretation:

Kohlberg characterized each level of resonse by interpreting the moral orientation of the subject (cf. 12.1 to 12.6). Levels 12.1 and 12.2 are early and middle childhood responses and together constitute a "Preconventional" Phase. Levels 12.2 and 12.3 are early adolescent and adult responses which constitute the "Conventional" Phase. Most individuals remain in this phase--living their lives in accordance with outer rules and expectations. Levels 12.5 and 12.6 are the "Postconventional" levels observed in some adults. This phase depends upon the achievement of Formal Operations. A Postconventional response is the application of an abstract concept (of individual rights and ethical principles) to an event or circumstance.

For the last twenty years Kohlberg's research has dominated the field of moral development. While we find some sense in his logical sequence, Kohlberg's theory has recently fallen under heavy criticism. One concern of Kohlberg's critics is the lack of available empirical data. Over the years, very little has been reported in raw form. Possible reinterpretations and replications have been hampered.

Kohlberg has claimed that his stages are universal, ordinal, and invariant, a claim consistent with Piagetian work. Each stage (here reported as an element of the response sequence) is the logically necessary precursor of the following stage. It is against this claim that psychologists and philosophers react most strongly.

If the stages of response are logically necessary, then the collection of data is unnecessary (Phillips and Nicolayev, in press). Science is defined by a dependence upon empirical validation of hypotheses which can be proven wrong. Both in the definition of his stages and in the use of data not made available for public scrutiny, Kohlberg has constructed an irrefutable and therefore unscientific theory. Furthermore, while he may be right in his intuitive perspective about moral development, his theory cannot generate predictions about moral action. Note that at any level, a subject may affirm or deny either course of action. Knowing that a subject is oriented to rules or laws does not imply which rules or laws will be obeyed.

We view Kohlberg's theory as an important early step toward a more comprehensive theory of social cognitive development. Just as Piaget's ideas have spawned many interesting alternatives, so Kohlberg's work in moral development has been seminal. Those who enter the moral development domain can begin by explaining the findings of Kohlberg.

13. TURIEL'S SOCIAL AND CONVENTIONAL REASONING SEQUENCE

Overview

Turiel (1975) has explored two specific aspects of moral development in the Kohlbergian and Piagetian tradition. First he explored the transition between Kohlberg's Conventional and Postconventional Phase, and detailed the transition state. Second, he explored the distinction between moral and conventional reasoning.

A conventional rule is one that serves a social regulatory function such as a dress code or a form of greeting. A moral rule is a more abstract principle, such as fairness or reciprocity. While Kohlberg posits that children mistake moral decisions for conventional decisions, Turiel explores the two domains separately.

Following in the Piagetian tradition, Turiel employs hypothetical stories and interview probes to gather data. His findings are:

Response Sequence

13.1. The child demonstrates no clear conception of a social system. Evaluation of social-conventional acts consists of applying rules when they are available. Decisions are arbitrary in situations with no rules.

The child understands moral issues to be separate from conventional ones and judges a moral event by the character of the act itself. Thus, stealing is always wrong.

13.2. The child indicates that conventional rules are arbitrary and unnecessary regulations placed upon individuals by their social groups. These rules are viewed with suspicion and the child prefers to examine the specific acts in question rather than simply to apply a conventional rule.

The child understands moral rules just as at level 13.1. That is, the relativism of conventional reasoning is not applied to moral events.

13.3. The child understands the underlying principles that support conventional rules. He indicates that a rule serves an important regulating function in a social group and can be modified fairly by that group. Moral decisions are also viewed in a relativistic manner. The act is no longer seen as a single critical event; rather, it is judged by its consequences for members of the social group.

Interpretation:

The first critical issue that Turiel explores is the apparent regression that occurs between responses 12.4 and 12.5 in Kohlberg's system. Early adolescents appear to regress to level 12.2, that is, they appear to take a perspective of instrumental relativism in social-conventional decisions. Turiel has established a "stage 4-1/2," which is a transitional stage between Kohlberg's Conventional and Postconventional Phases.

By distinguishing between conventional and moral reasoning, Turiel argues that this transitional stage is caused by a misalignment of social-conventional versus moral development. The moral response remains stable at level 4 while the conventional response advances. A realignment occurs at stage 5 and all is again consistent.

Turiel's distinction between conventional social and moral decisions is important. While we may trace a child's development with respect to conventional standards such as "manner of address" and see relatively slow accommodation with the accepted adult standards, Turiel points out that in ethical areas the development is more rapid. Furthermore, we speculate that in a domain such as environmental studies, where no common "conventional" set of rules exists, we will have to wait a longer period of time before adolescents construct stable codes of action.

14. SELMAN'S PERSPECTIVE AND ROLE TAKING SEQUENCE

Overview

When Piaget (1929) described young children's cognitive behavior as egocentric, he isolated a dimension of cognition that might be especially useful in understanding social interaction. Selman and others have reversed the direction of Piaget's construct to explore the child's growing ability to take the role or perspective of other persons.

Two common paradigms in perspective-taking research are the "Three Mountains Task" from Piaget (1964) and the tasks that depend upon "privileged information" from Flavell, et al. (1968). In the Three Mountains Task, a child is asked to construct the view of another person looking at a triangular display of "mountains." In the Privileged Information Task, the target child is given more information about a situation than another person. The child is asked to predict the other person's response to the situation and the responses are coded both with respect to the appearance of information that the subject knows but the other person does not (i.e., egocentric) as well as the degree of accuracy with which the other person's perspective is described (perspective and role-taking ability). Selman combined both of these methods in a complex experiment involving a set of booths and displays visible to only certain persons. Later he described a "structural analysis" of perpective-taking skills in reinterpreting the findings of other researchers.

Response Sequence

14.1. The child reports that the perspective of other persons is the same as his or her perspective. While the child does differentiate self from other, he or she fails to recognize that others see things differently.

14.2. The child can construct the perspective of another individual in a social group. The child is unable to coordinate another person's perspective with his or her own, or with the perspectives of the other members of the group. That is, the child is limited to predicting one other view.

14.3. The child can construct the perspective of another individual and include his or her own perspective in the other's view. The child cannot coordinate the views of other members of the group. The child's perspective-taking ability is limited to understanding the view of one other person and his or her own perspective.

14.4. The child is able to construct a "generalized" perspective in a social group situation. He or she can construct the view of an outside spectator looking in on the circumstances.

14.5. The child is able to see the limitations of a "generalized" perspective and is able to coordinate an overview understanding of the situation with individual perspectives of the participants.

Interpretation:

Selman's work is important because he pulls together the findings of a major group of social cognition researchers. His broad stages are intuitively appealing and align broadly with the findings of others. Because the levels are general statements, the possibility of drawing inferences for education and curricula seems strong.

Our reservation about Selman's work centers on the problem of the social group. These stages refer to a child's ability to abstract various perspectives and to coordinate needs in some soial domain. Most of the studies Selman reviewed were experiments in which a child was placed in a small group of peers in a relatively clear, spatially oriented task. Most real social circumstances, particularly those which relate to educational goals and environmental studies, concern very large groups of people, most of whom are adults attempting to decide abstract, complex, and subtle issues. We have no information about a child's perspective-taking skills in mixed groups of adults and children. We have limited information about the kinds of perpectives a child is able to coordinate.

15. DAMON'S DEVELOPMENT OF POSITIVE JUSTICE SEQUENCE

Overview:

Damon's recent book, *The Social World of the Child* (1977), is a state-of-the-art view of social cognitive research. In both his methodology and his interpretations, Damon reflects the trends and avoids the problems of the work previously mentioned (i.e., Piaget, Kohlberg, Turiel, and Selman). Like Piaget, Damon investigates both the child's explanation of a social event (i.e., uses hypothetical stories) and the child's behavior in naturally occurring social interactions. Damon is interested in developing stages of social understanding just as Kohlberg was, but he is careful to examine the transitions between stages and to distinguish between moral and conventional themes. He integrates his findings with the structural analyses of Selman.

While Damon has explored three other dimensions of social cognition (friendship, obedience, and social regulation), we will describe his work in the area of positive justice. For Damon, positive justice refers to the child's understanding of how to distribute materials fairly in a social group. Damon's experiments are of two kinds. First he interviewed children, probing their understanding of stories which concern distribution of limited resources. Second, he conducted parallel laboratory experiments. Children were asked to construct necklaces. Interrupting at a point when the number of completed necklaces differed among the children, the experimenter produced an odd number of candy bars to be distributed. Data were gathered by interviewing the children individually to determine their reasoning about this "real-life" situation.

Damon describes a sequence of six responses typical of children from three to ten years. We will condense these six levels into three more general levels for discussion here.

Response Sequence

15.1. The child distributes resources to persons with favored characteristics. Decisions are often self-serving and these characteristics do not align with the needs, abilities, and contributions of the individuals.

15.2. The child distributes resources in an arithmetically equal manner. Either each person is given an equal amount or each person is given an amount exactly equal to his contribution to the group. Thus, some children may not be allocated any resources.

15.3. The child balances the concern for arithmetic equality with a concern for the abilities and needs of each person. If some children are very young and have not been able to contribute to the group, then they still will receive some of the resources. The child recognizes that a fair distribution is a weighted distribution, with each person receiving some of the resource.

Interpretation:

Damon has found ways in which to allow children to demonstrate social reasoning at a relatively early age. By the beginning of the Representational Period, Damon found children able to employ a coordinated system of merit weights and individual dispositional weights in order to divide resources fairly. Clearly the natural experimental conditions he employed are critical to these positive findings. Damon observed exactly those kinds of situations with which children are most well acquainted.

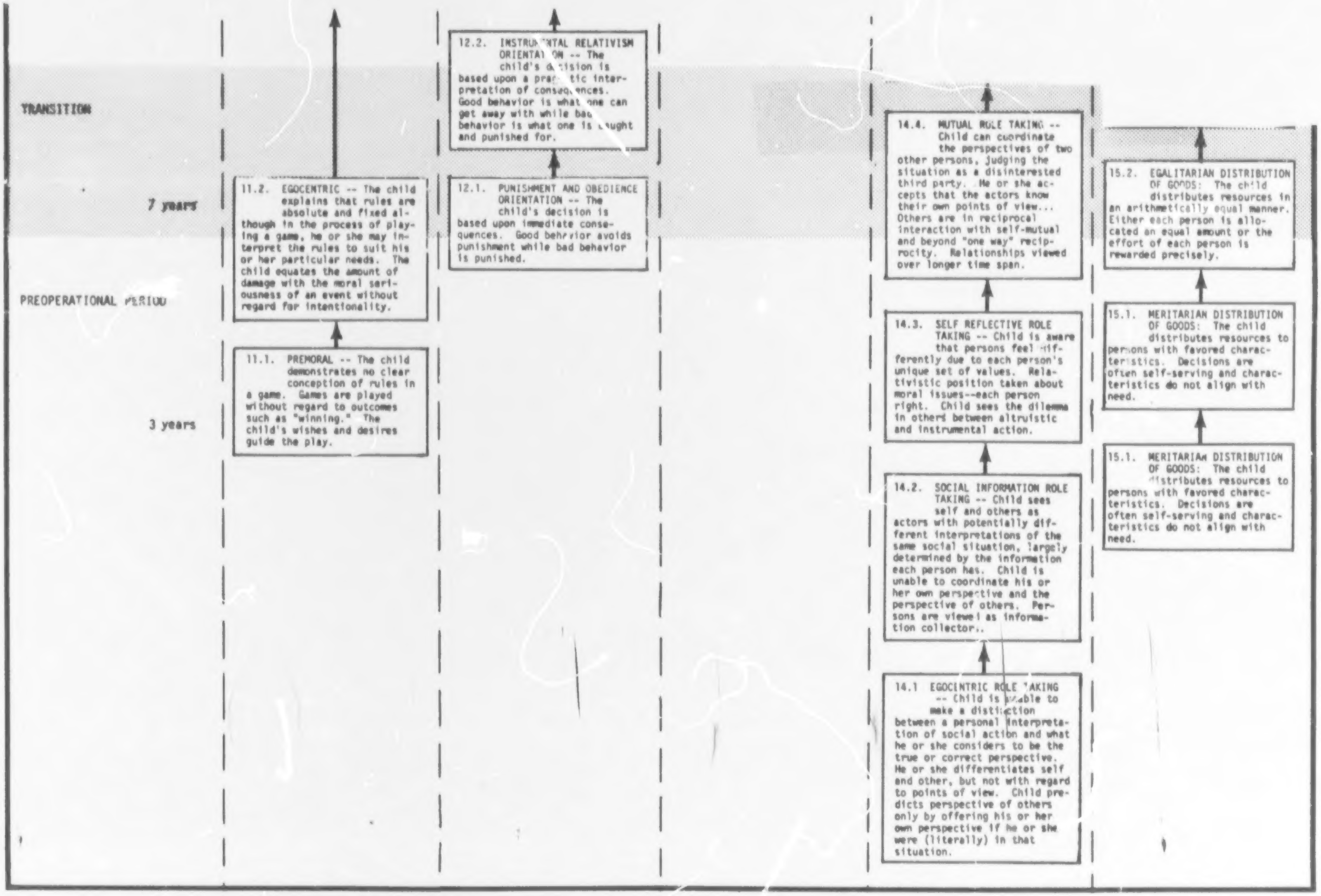
Unfortunately, Damon has not extended his approach to older children and thus we can not make any generalization about the changes in positive justice that occur during the Formal Operational Period.

As is the case with other social cognitive findings, the question of interpretations and implications for curricula and education is most difficult. Damon cautions his readers that while his subjects do demonstrate the ability to distribute resources in accord with an eclectic, egalitarian, meritorious and benevolent philosophy, there is "no direct relation to similar-sounding ideas when applied by adults to the complex distribution problems of their social world" (Damon, 1977, p. 77). Thus, we are left waiting for further studies before we can make stronger statements about the development of social cognition.

CHART A-3: TASKS THAT ILLUSTRATE THE DEVELOPMENT OF SOCIAL COGNITION

DEVELOPMENTAL PERIOD	TASK 11: PIAGET'S MORAL DEVELOPMENT SEQUENCE	TASK 12: KOHLBERG'S MORAL DEVELOPMENT SEQUENCE	TASK 13: SOCIAL CONVENTION AND MORAL JUDGMENT SEQUENCE	TASK 14: SELMAN'S PERSPECTIVE AND ROLE TAKING SEQUENCE	TASK 15: DAMON'S POSITIVE JUSTICE SEQUENCE
FORMAL PERIOD 13+ years		12.6. UNIVERSAL ETHICAL PRINCIPLE ORIENTATION -- The child's decision is based upon the application of abstract and universal principles such as reciprocity, equality, and respect for human life. Good behavior is not necessarily defined by context but results from application of these principles. 12.5. SOCIAL-CONTACT LEGALISTIC ORIENTATION -- The adult's decision is based upon the standards established within a social group. Laws are a reflection of the needs and rights of members of the group and can be changed. Good behavior is defined within and by one's social context.	13.3. Social-conventional acts judged in an interactive social context -- no longer arbitrary or unnecessary. Social acts judged with respect to social system from which they emanate. Consensus is the basis for rules. Society viewed as hierarchically structured --some members subordinate to others.		
TRANSITION 11 years	11.4. GENUINE COOPERATION -- The child explains that rules are formed by the consensus of the players and may be changed. Intentionality becomes the criterion for judging moral seriousness.	12.4. "LAW AND ORDER" ORIENTATION -- The decision of the child or adult is derived from the application of a rule or law. Laws produce order on one's society. Good behavior is understood to be doing one's duty and obeying the law.	13.2. Rules are prescriptions set down by individuals (parents, teachers) or institutions (schools). Social-conventional acts are viewed as arbitrary and unnecessary; s-c rules as constraining. Moral acts are judged in a descriptive (vs. prescriptive) manner, however.		
REPRESENTATIONAL PERIOD 9 years	11.3. INCIPIENT COOPERATION -- The child continues to view rules as fixed and unchangeable but can follow the rules of a game more accurately. The amount of damage remains the criterion for deciding moral seriousness.	12.3. INTERPERSONAL CONCORDANCE ORIENTATION -- The decision of the child or adult is based upon the standards established by others for personal behavior. Good behavior "is nice" and conforms with what a "good girl" or a "good husband" is expected to do.	13.1. Child reveals no clear conception of social system, no distinction between moral and conventional judgments. Evaluation of social-conventional acts varies with the availability of rules; moral acts evaluated as intrinsically good or bad. Rules also viewed as intrinsically good or bad.	14.5 SOCIAL AND CONVENTIONAL SYSTEM ROLE TAKING -- Child's perspective raises from dyadic to the level of social systems involving group perspectives. Child sees "generalized other" (i.e., the social system's collective perspective). Decision making involves the full complexity of interactions between individual beliefs, attitudes, and values with respect to an overall system of expectations of the social system (i.e., the "generalized other").	15.3. BENEVOLENT DISTRIBUTION OF GOODS: The child distributes resources in a manner that coordinates equality and individual circumstances. Prior deprivation or special needs are considered as well as effort. The child recognizes that precise equality of distribution may not be as fair as a weighted distribution with each person receiving some of the resources.

{continued on next page}



11.1. PREMORAL -- The child demonstrates no clear conception of rules in a game. Games are played without regard to outcomes such as "winning." The child's wishes and desires guide the play.

11.2. EGOCENTRIC -- The child explains that rules are absolute and fixed although in the process of playing a game, he or she may interpret the rules to suit his or her particular needs. The child equates the amount of damage with the moral seriousness of an event without regard for intentionality.

12.1. PUNISHMENT AND OBEDIENCE ORIENTATION -- The child's decision is based upon immediate consequences. Good behavior avoids punishment while bad behavior is punished.

12.2. INSTRUMENTAL RELATIVISM ORIENTATION -- The child's decision is based upon a pragmatic interpretation of consequences. Good behavior is what one can get away with while bad behavior is what one is caught and punished for.

14.1 EGOCENTRIC ROLE TAKING -- Child is unable to make a distinction between a personal interpretation of social action and what he or she considers to be the true or correct perspective. He or she differentiates self and other, but not with regard to points of view. Child predicts perspective of others only by offering his or her own perspective if he or she were (literally) in that situation.

14.2. SOCIAL INFORMATION ROLE TAKING -- Child sees self and others as actors with potentially different interpretations of the same social situation, largely determined by the information each person has. Child is unable to coordinate his or her own perspective and the perspective of others. Persons are viewed as information collectors.

14.3. SELF REFLECTIVE ROLE TAKING -- Child is aware that persons feel differently due to each person's unique set of values. Relativistic position taken about moral issues--each person right. Child sees the dilemma in others between altruistic and instrumental action.

14.4. MUTUAL ROLE TAKING -- Child can coordinate the perspectives of two other persons, judging the situation as a disinterested third party. He or she accepts that the actors know their own points of view... Others are in reciprocal interaction with self-mutual and beyond "one way" reciprocity. Relationships viewed over longer time span.

15.1. MERITARIAN DISTRIBUTION OF GOODS: The child distributes resources to persons with favored characteristics. Decisions are often self-serving and characteristics do not align with need.

15.1. MERITARIAN DISTRIBUTION OF GOODS: The child distributes resources to persons with favored characteristics. Decisions are often self-serving and characteristics do not align with need.

15.2. EGALITARIAN DISTRIBUTION OF GOODS: The child distributes resources in an arithmetically equal manner. Either each person is allocated an equal amount or the effort of each person is rewarded precisely.

CHART A-3: TASKS THAT ILLUSTRATE THE DEVELOPMENT OF SOCIAL COGNITION {cont.}

APPENDIX B:

A SPECULALATIVE EXTRAPOLATION OF AN INFORMATION PROCESSING MODEL OF DEVELOPMENT

Fischer (in press) has proposed that a basic pattern: set, mapping, reversibility, system/higher order set, is common to the Sensorimotor Period and the Representational Period. He extends this pattern to the beginning of the Formal Operations Period (Stage 7) and then stops. As an experimental scientist, he must do so since there is no data to support its further extension. Fischer suggests, however, that the same pattern may occur again during the Formal Period and perhaps still a further cycle could occur beyond that. Likewise, Case (1978a) suggests that there may be third order operations that define an adult period beyond Formal Operations.

We were intrigued by these suggestions since they seemed relevant to both the preparation of this monograph and to the more general problems of environmental communication. We developed a speculative extrapolation, which we include here primarily to trigger the thoughts of our readers.

We began by asking ourselves exactly what the model or worldview we called "developmental psychology" really was. One of us approached this monograph from the perspective of a system analyst; another came from a predominantly behavioral perspective; and still another came from the developmental perspective. We often found ourselves translating one or another aspect of developmental psychology into our other language or metaphor system. And we could not help but think that we were trying to map one Formal system onto another. In the end we even thought that we might have developed reversibility between our various perspectives.

To place these intellectual efforts in a sequence, we extrapolated Fischer's system to thirteen levels (See Table B-1). Since a large number of adults fail to move decisively into Formal Operations it is hard to think of Stages seven through thirteen as associated with age at all. Furthermore, since there is no experimental evidence to support this extrapolation it is of no immediate pedagogical use.

STAGE		EXAMPLES
Stage 13	Second-order metasystems	Meta-languages that attempt to allow their users to see the elements common in all metasystems (e.g., mathematics, general systems, poetry.)
Stage 12	Metasystem reversibility	Explaining an event in terms of either Developmental Psychology or Behaviorism. The complementary principle in physics
Stage 11	Metasystem mapping	Explaining Developmental Psychology in terms of Behaviorism
Stage 10	Formal system or a simple metasystem	Genetic Epistemology or Behaviorism
Stage 9	Formal reversibility	Capable of analyzing a very complex situation entirely in terms of stimuli, responses, consequences, and schedules of reinforcement
Stage 8	Formal mapping	Explaining various actions in terms of schemata or operants
Stage 7	Representational system of a simple formal set	Concept of volume or the idea of an operant or a Piagetian schemata
Stage 6	Representational reversibility	Thinking about a thing by switching back and forth between one concept and another
Stage	Representational mapping	Explaining one concept by analogizing it to another concept
Stage 4	Sensorimotor system or simple Representational set	A concept-word or image
Stage 3	Sensorimotor reversibility	Object permanence
Stage 2	Sensorimotor mapping	Secondary circular reactions
Stage 1	Simple sensorimotor set	A Piagetian schemata; a behavioral operant

Table B-1. EXTRAPOLATION OF FISCHER'S MODEL TO THIRTEEN LEVELS

As environmentalists, however, our very speculative extension made a kind of intuitive sense since we have commonly found ourselves trying to explain problems that arise when economists or lumbermen interact with ecologists and government planners. We suggest that the progression from simple Formal sets (Stage 7) to a simple metasystem (Stage 10) is, in fact, the progression from simple abstract concepts to an abstract, but highly integrated worldview. Such a worldview, if it is pondered over several years, becomes the dominant perspective from which an intelligent person approaches any serious intellectual problem. A psychologist who earns a Ph.D. in developmental psychology learns to conceptualize almost any problem in terms of development. A business-person who pursues a career in industry learns to conceptualize all serious problems in business terms. A physician learns to think of problems in medical terms. As formal adults spend a large amount of time thinking in terms of the network of relations, implications, and general theories common to their intellectual specialty, they develop great skill and subtlety in using their particular metasystem to conceptualize almost any problem.

Metasystem mapping also makes sense as a rapid way of coming to grips with a new Formal system. Once we translate a new system (e.g., developmental psychology) into our predominant Formal system (e.g., behaviorism) we can then apply all the transformations we commonly apply to our own system and see what results. A danger arises when individuals who have specialized in one Formal system stop at Stage 11 and believe that their particular metasystem is completely comprehensive and that any other Formal system can be completely translated into and understood in terms of their predominant metasystem.

Ideally, when we compare and contrast two metasystems at Stage 12, we realize that the world is too complex to be mapped by any one Formal system, and attempt to live with that higher dynamic equilibration that seeks understanding in the constant clash and synthesis of different metasystems. Some go on and try to develop a higher order meta-language (a second order metasystem) that will enable one to identify the common elements of all metasystems. We suggest that this more or less describes the crisis faced by physicists who sought to choose between a particle and a wave model for subatomic particles. The solution--the complementarity principle in physics--is an example of Stage 12 (Metasystem reversibility).

At their very best, mathematics, General Systems Theory, and literature aspire to the thirteenth level. We suggest that just such a perspective was what Wittgenstein sought to convey in his Philosophical Investigations.

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